Improving the Sustainability of Drinking Water Desalination in Cape May, NJ

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Executive Summary

Access to safe drinking water and sanitation is an inalienable human right. This capstone project seeks to provide information, analysis and recommendations in support of the long-term sustainability of Cape May City's water supply. The project was conducted in collaboration with the Cape May Mayor's Office and the City's Public Water System, both of which are committed to the continuous provision of safe and reliable water to all residents and businesses within their jurisdiction.

Cape May, located at the southernmost tip of New Jersey, is a historic town originally inhabited by the Lenape tribe and formally established as a city in 1614. The city is a major summer destination for seasonal residents, attracted by the town's scenic beaches and surrounding waterways. Despite being surrounded by water, the city lacks access to potable water sources and is entirely reliant on an aging desalination plant to meet the needs of its residents, seasonal visitors, and local businesses.

Cape May faces a unique set of water-related challenges intensified by its fluctuating population and infrastructure limitations. The current desalination plant, which will be decommissioned soon in favor of a new facility, operates under increasing strain and faces long-term sustainability concerns.

This project highlights three critical issues currently facing Cape May's water system: (1) The over-extraction of groundwater from local aquifers; (2) The operational challenges of running a desalination plant; and (3) A lack of public awareness and community engagement in water conservation. To address these issues, the project is structured around four key workstreams: Water Circularity, Desalination Operations, Water Demand, and Financial Viability.

Through research, engagement with city officials, and innovative planning, each workstream has led to the development of targeted solutions: identifying higher-value uses for concentrate, exploring energy recovery technologies for more efficient operations in the new desalination plant, developing a "Water Demand Playbook" to guide conservation behavior, and assessing the feasibility of solar installations to reduce operational costs at city government sites.

Together, these strategies form a roadmap aimed at helping the city secure its long-term water future. This capstone project supports actionable steps to help city officials safeguard this vital resource for generations to come.

Introduction

2.1. Cape May City Overview

In Cape May City, New Jersey, water is both the city's greatest asset and most troubling liability. Located on the southernmost tip of New Jersey at the end of the Cape May Peninsula where the Delaware Bay meets the Atlantic Ocean, the city is nearly completely surrounded by salt water. In the southwest corner of the Peninsula, nestled among the wetlands, sits Lake Lily — one of the few sources of freshwater. This historic freshwater lake served as a critical resource for the original Native American population and subsequent Dutch settlers and continues to play a vital role in sustaining key populations of migratory birds passing through on their seasonal journeys (Neff, 2020).

The convergence of freshwater and saltwater produced Cape May's two largest industries, commercial fishing and tourism. The success of Cape May's commercial fisheries saw the city grow to its current population of approximately 3,000 permanent residents, with this number exploding to over 70,000 residents in summer months. In order to sustain its population growth, the city migrated from utilizing Lake Lily for potable freshwater to extracting water from underground aquifers, leading to the construction of a brackish water desalination plant in 1998. This solution, however, was not without its issues. Due to consumption levels and local commercial engineering projects, saltwater intrusion into the aquifers has continued to present an issue. Despite this advanced solution, the reality today is that the current desalination plant (the Plant) is in dire need of replacement if it is to continue meeting the water demands of the city's highly variable population. The city is already in the planning process for the new plant. Many of the recommendations in this report can aid in mitigating strain during the transition period and in addressing both demand and supply best practices so that the city and its economy can continue to prosper without inordinate demand on water resources.

2.2. Water Infrastructure Evolution

Cape May City has a long-standing history of addressing its water supply needs through innovative infrastructure development and resource management. The city's evolution from relying on shallow groundwater to advanced brackish water desalination technology reflects its adaptive response to environmental pressures such as saltwater intrusion.

Cape May City's public water system was established in 1910 to ensure a reliable and centralized source of potable water for residents (City of Cape May, n.d.). This marked the beginning of its municipally-managed water infrastructure as the city sought to prepare for growth and future demand.

2.2.1. Aquifer Transitions And Desalination

Between 1950 and 1998, Cape May drew its water primarily from three wells tapped into the Cohansey Aquifer, a shallow aquifer that is part of the Kirkwood-Cohansey aquifer system. This system stores approximately 17 trillion gallons of fresh water and supports much of South Jersey's ecological and human needs (City of Cape May, n.d.). However, as water demand increased and the amount of water withdrawn from the aquifers increased with it, the city began experiencing saltwater intrusion with saline water seeping into the freshwater aquifers and threatening the integrity of its supply. This environmental challenge made it necessary for the city to consider deeper aquifers and alternative treatment technologies.

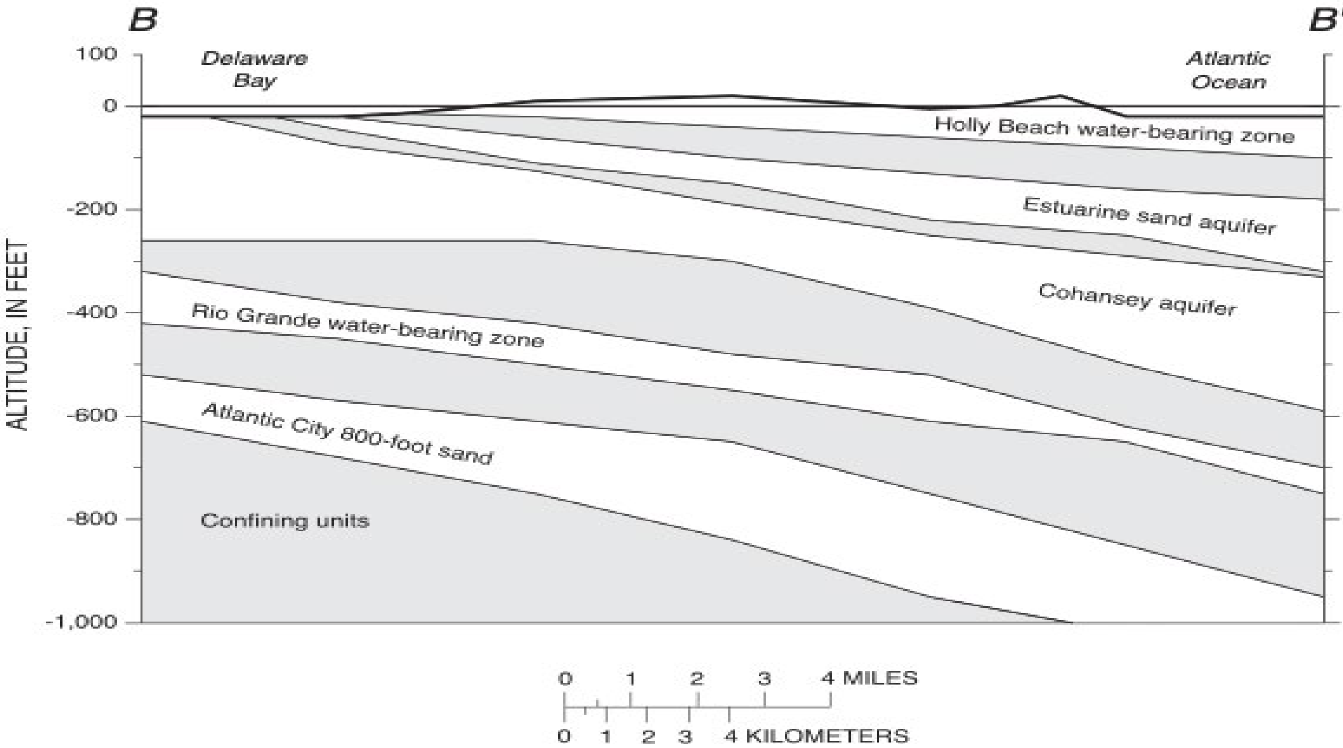
In response to saltwater intrusion, Cape May became a pioneer in municipal brackish water desalination in the northeastern United States. In late 1997, the city drilled the first of several new wells, and by July 1998, it had commissioned a state-of-the-art desalination plant housed in the historic Water Works building.

Today, Cape May operates three wells that draw from the deeper Atlantic City 800-foot sand aquifer and one that still draws from the Cohansey Aquifer

Figure 1: Cape May Water Works Building
Photo by Authors

The reverse osmosis system treats brackish groundwater–partially salty water from the deeper Atlantic City 800-foot sands aquifer and provides a steady, potable supply to the community.

Figure 2: Hydrostratigraphy In Cape May
Source: (USGS, 2002).



2.3. Key Challenges

2.3.1. Overwithdrawal From Aquifers

The Atlantic City 800-foot sand aquifer has the capacity to serve as the primary source of water for southern New Jersey's coastal communities for many years. The region's extensive development and the connected increase in water demand over the last several decades, however, has placed unprecedented stress on this aquifer and yielded several localized issues.

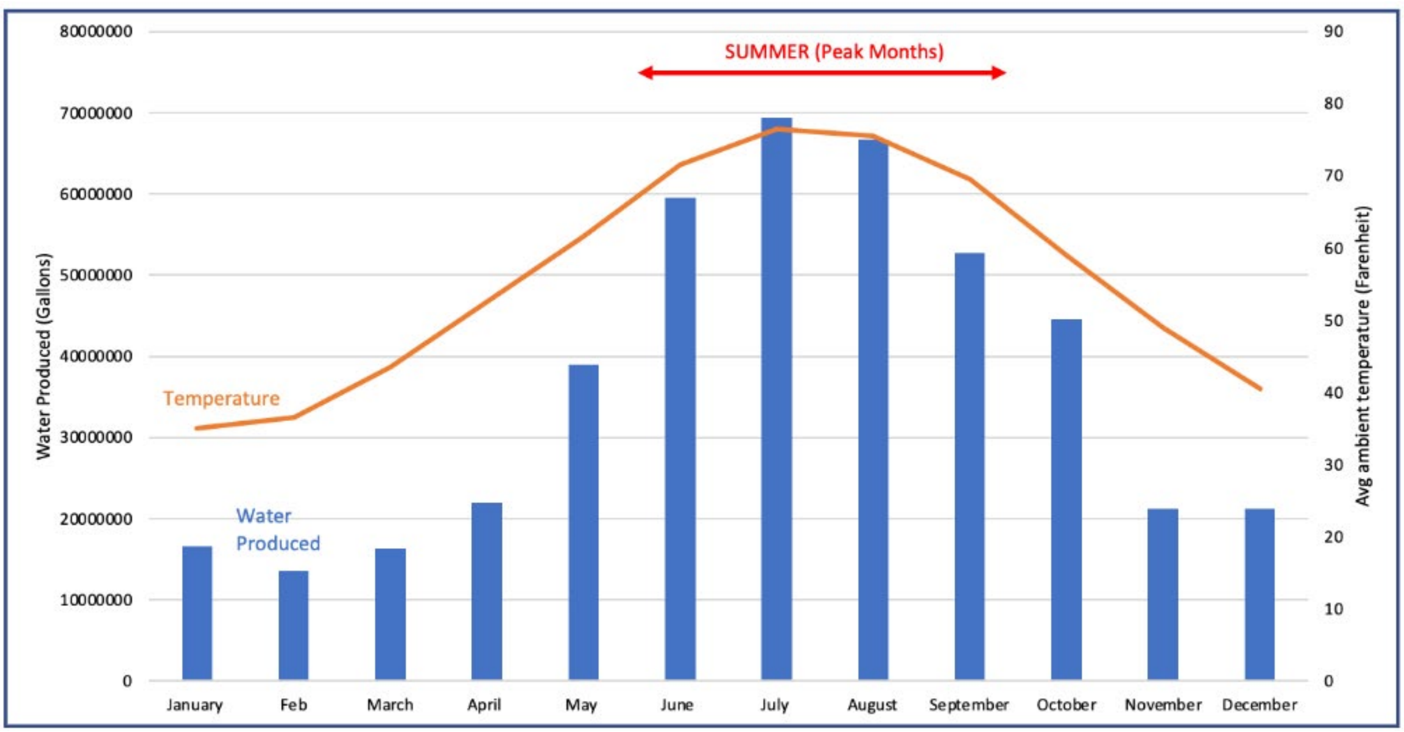
The effects of the region's water withdrawals on this aquifer are evident in two key ways. First and foremost: the decreasing water levels within the Atlantic City 800 foot sand aquifer serve as a direct reflection of the region's reliance on this aquifer. Although the aquifer is significant in size, there is scientific research that points to a drop in water level due to withdrawals. A 2001 United States Geological Survey study found that, by that time, groundwater levels within the Atlantic City aquifer had already declined to about one hundred feet below sea level near Atlantic City since 1986 (McAuley et al., 2001). Since then, groundwater modeling has projected continuing decreases in water levels throughout the aquifer (NJDEP, 2017, p. 4). While opinions may differ on the rate or rapidity of change, ample evidence remains of the continuing impact of withdrawals on the aquifer's water levels, and the issue of saltwater intrusion that this precipitates.

The second way in which these withdrawals are reflected within the aquifer's hydrology is with regard to the phenomenon of saltwater intrusion mentioned above. Saltwater intrusion fundamentally occurs due to a phenomenon known as a "cone of depression"— the cone-shaped water level within an aquifer that results from water withdrawal. Cones of depression are localized and centered around the pumping wells, and result in a reversal of the natural hydraulic gradient. In other words, the balance of the pressure differential between the aquifer's freshwater and the bordering saltwater is altered, thus allowing the saltwater to intrude further into the freshwater aquifer. Ultimately, saltwater intrusion yields increased chloride and sodium concentrations which complicates the desalination processes.

2.3.2. Peak Season Tourism Water Demand

Cape May City's high influx of seasonal population presents a variety of challenges for the water system. Primarily, the amplified strain placed on the desalination plant during the summer months increases risks of breakdowns and service interruptions. Increased demand on the desalination plant results in increased strain on the aquifers which leads to the negative effects identified in the previous section. This is particularly true of the one shallow well, used only to support peak demand.

Figure 3: Water Production By Month
Created by Authors, Data Source: City of Cape May



Seasonal populations also present unique challenges for water conservation efforts. Temporary residents are less likely to have any interest in participating in water conservation initiatives, which may result in tensions between Cape May City's temporary and permanent residents. At the same time, however, these temporary residents are also essential to the city's economic well-being in that tourism serves as a pillar of Cape May City's economy.

Addressing the vulnerabilities of Cape May's water system is a complicated challenge that requires balancing multiple, and sometimes competing, priorities. To ensure long-term environmental sustainability and adequate supply, the city should adopt measures that promote reasonable demand even during peak season. This approach could protect the aquifers from overuse, ensure the reliability of the desalination infrastructure, and uphold the best interests of the city's permanent population. Ultimately, sustaining both economic prosperity and environmental resilience could depend on forward-thinking solutions that align tourism growth with the city's long-term water security goals.

2.4. Project Scope

2.4.1. Deliverables Overview

2.4.1.1. Circularity

In order to support Cape May's efforts to build a climate-resilient and economically sustainable water system, the Circularity Team evaluated potential value streams for the 109 million gallons of concentrate generated annually by the city's desalination plant. Guided by the principle of circularity — that all waste products must be understood as resources and used to their highest possible value — the team sought to reframe this byproduct not as waste, but as a potential input into other value chains. Our analysis is organized around three core deliverables: (1) An economic analysis of end-use applications, including salt recovery, mineral and rare earth element extraction, and irrigation reuse; (2) Identification of potential buyers across each market; and (3) An overview of the industrial processing requirements needed to make the concentrate market-ready, ranging from evaporation and crystallization systems for salt and minerals to light filtration for direct reuse in landscaping. Collectively, these deliverables highlight the potential to transform this overlooked desalination plant byproduct into a diversified, revenue-generating asset that advances both environmental and fiscal goals.

2.4.1.2. Desalination

To support Cape May's long term water security strategy, the Desalination Team conducted an assessment of the current desalination plant's operational performance and explored opportunities to enhance the sustainability of the city's water infrastructure. The team's analysis was structured around one key deliverable: A comparative study of design and technology options for the proposed new facility, with a focus on sustainable practices including renewable energy integration and advanced energy recovery devices. These findings provide Cape May with additional information and references during its current efforts to modernize its desalination infrastructure, reduce lifecycle emissions, and future-proof its water supply in the face of climate stressors and rising demand.

2.4.1.3. Demand

The long-term realization of water security in Cape May relies on raising awareness about the value of water and promoting conservation to reduce overall demand. To better understand current consumption patterns, the Demand Team conducted a water demand analysis based on information provided by the City. Based on the findings, the team recommends considering a tiered pricing system to manage demand by disincentivizing high-consumption activities while rewarding conservation. To complement this financial disincentive, the team also proposes rebates for installing water-efficient appliances. This approach is especially relevant for the hospitality industry, which has notably high water usage but remains a key driver of Cape May's economy. For the policy to be effective, it is essential that multiple stakeholders not only understand, but actively support, tiered pricing or any other broader conservation efforts. To support this, the team is offering models for an education and engagement strategy aimed at key audiences such as the hospitality sector, permanent and seasonal residents, and the media.

The Demand Team's recommendations are accompanied by a proposed timeline to support the city in deciding how and when to implement strategies such as these for optimal results.

2.4.1.4. Finance

In order to guarantee access to reliable potable water for years to come, Cape May City needs to ensure that municipal water infrastructure is operated sustainably from both a financial and environmental perspective. Economic viability is a key element of sustainable operation and minimizes the financial burden on the municipality and taxpayers. Cape May City has a strong track record of fiscal responsibility and the city's water and sewer infrastructure is operated on a profitable basis today. Responsible financial management has enabled the municipality to accumulate a capital surplus, which provides protection against unexpected future costs and allows for strategic capital investment.

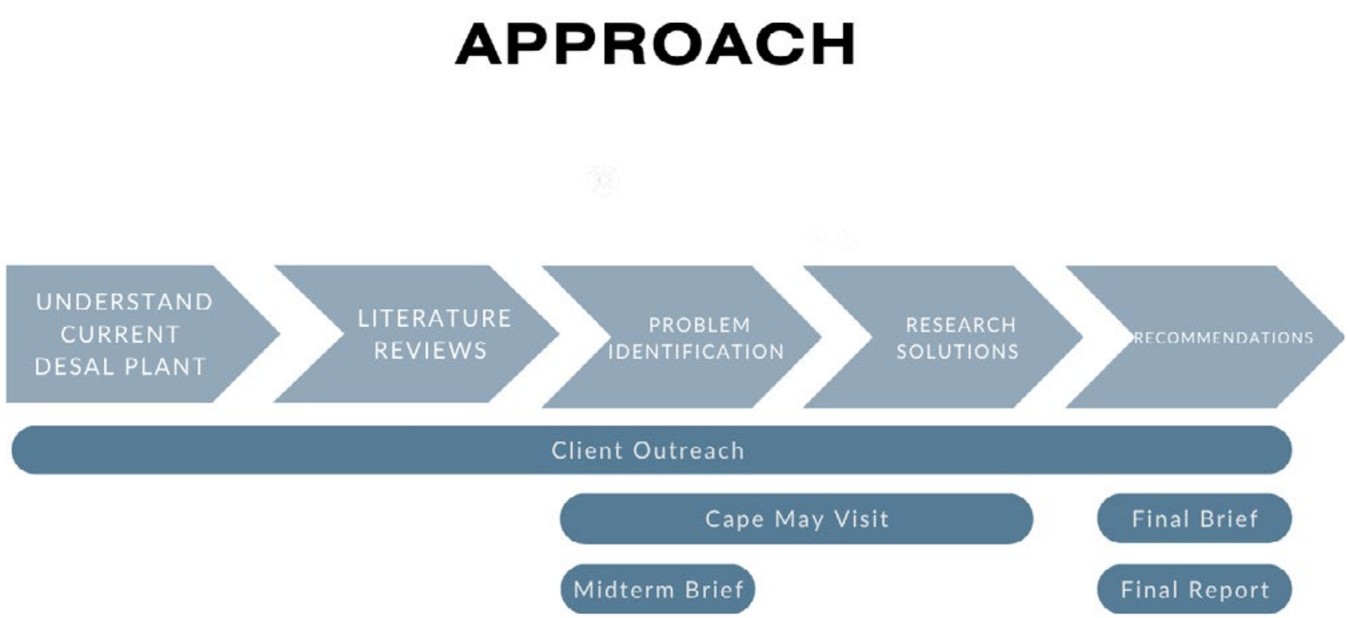
In the financial section of this report, we will evaluate the recommendations presented in prior sections from an economic perspective. Our goal is to estimate the net financial impact of the major solutions contemplated: (1) launching a rebate program for water-efficient fixtures; (2) installing energy energy recovery devices at the desalination plant; and (3) developing onsite photovoltaic solar generation at the desalination plant. The hope is that our illustrative financial analysis will help Cape May City decision-makers confidently weigh social, environmental, operational, and financial trade-offs. Ultimately, having a clear view of the financial impact of new initiatives may allow the city to continue to maintain strong fiscal discipline and operate infrastructure in a sustainable manner, in both the fiscal and the larger environmental sense. (Refer to pag 49, Financial Feasability).

Analytical Approach

3.1. Research Approach

In order to ensure that the insights and recommendations presented in this report are both useful and grounded in Cape May's unique context, our team pursued an analytical approach rooted in transparency, adaptability, and purpose-driven research. Rather than relying on a single standardized methodology, such as a cost-benefit model or water stress index, we opted for a more modular and responsive framework that is tailored to the distinct demands of each research stream.

Figure 4: Research Approach
Created by Authors



For technical and engineering components, we consulted case studies, industry best practices, and expert interviews to assess practical opportunities for enhancing the current desalination plant and improving the design of the planned facility. In contrast, policy-oriented solutions — such as the proposal for tiered pricing — were developed through comparative analysis of how such structures have been deployed in cities across the US and abroad, with attention to equity, conservation outcomes, and administrative feasibility.

Throughout, the team was careful to define and articulate the assumptions underlying our analysis. The team recognizes that Cape May is in a unique position: surrounded by water, but reliant on aging and complex freshwater infrastructure. The perception of water as abundant can obscure its true financial and ecological cost (Cauberghe et al., 2021). The team approached each workstream with sensitivity to local dynamics and a commitment to presenting balanced, adaptable options rather than prescriptive answers.

The goal of the team is not to dictate direction, but to equip the City of Cape May with tools, references, and framing to make informed and forward looking decisions. Each section of this report reflects the analytical logic and research pathways taken by individual teams, which are further detailed in the "Team Roles and Workstream" section that follows. Follow (Refer to pag 13-14, 3.2. Team Roles and Workstream).

3.2. Team Roles And Workstream

3.2.1. Circularity

The Circularity Team explored commercial opportunities for the Plant's concentrate in order to minimize waste generated by the desalination process, and categorized these opportunities based on the form of the concentrate. For the use of the concentrate in liquid form, we explored potential opportunities to offset demand for the potable water otherwise being used for landscape irrigation. In this application, we focused on the most significant consumers of water for irrigation purposes within Cape May by analyzing water consumption data provided by the Cape May Water Department. We also explored potential opportunities to sell the concentrate to neighboring communities for use to the same effect. To do so, we leveraged a US Geological Survey case study on the largest consumers of water on the Cape May peninsula. Finally, in order to identify the concentrate's potential "solid form" revenue streams, we analyzed case studies on the potential value of the variety of minerals and elements that may be extracted from it.

3.2.2. Desalination

The Desalination Team analyzed the operational efficiency and energy usage of the existing desalination plant by performing a detailed utility bill analysis to quantify current energy consumption patterns and identify potential savings. Additionally, we assessed critical operational data provided by the plant's SCADA monitoring system, including metrics related to antiscalant use, maintenance cycles, and overall system performance. Another important part of our work involved evaluating energy recovery devices (ERDs), specifically turbochargers and pressure exchangers, that could significantly reduce the plant's energy demands, and improve overall efficiency. We collaborated closely with the Finance Team in order to assess economic feasibility and cost implications for implementing either of these ERDs. We also derived valuable insights from one meeting with the engineers designing the new plant, in addition to regular discussions with the desalination operations team in Cape May. These collaborations helped us ensure our recommendations are realistic, informed, and aligned with Cape May's infrastructure goals for a successful and sustainable desalination plant.

3.2.3. Demand

The focus of the Demand Team was assessing the most effective strategies that might be adopted to reduce water demand in Cape May City. We established three primary initiatives: tiered pricing, engagement (business and community) and incentivizing water-efficient technologies. Each member of the Demand Team took on one of these initiatives. As these initiatives are intended to be woven together into a larger water conservation proposal, the team carefully considered opportunities for collaboration across initiatives. The Demand Team also collaborated with the Finance Team to conduct financial analysis on the different water conservation initiatives.

3.2.4. Finance

The Finance Team was responsible for evaluating the economic viability and impact of the concrete report recommendations: (1) launching a rebate program for water-efficient fixtures; (2) installing energy recovery devices at the desalination plant; and (3) developing onsite photovoltaic solar generation at the desalination plant. For the rebate program, we evaluated the lifetime cost and water savings from installing water-efficient fixtures at the unit, customer, and municipal levels using guidance from the U.S. Environmental Protection Agency (EPA). For the energy recovery devices, we calculated the payback period and lifetime cost savings from installing three units using energy consumption data from the existing plant and performance data from comparable case studies. For the onsite solar, we estimated potential power generation at the site and cost savings on utility bills using a solar-mapping software tool and historical utility bills from Cape May City.

3.3. Site Visit To Cape May

We visited Cape May City and the larger Cape May peninsula during the semester to experience the place that we are making recommendations for, firsthand. With this trip, we sought to gain local context, meet the people who will review and hopefully implement some of our suggestions, and get feedback to inform the ways in which our project may be most valuable to the city of Cape May.

Through activities including touring the current desalination plant and attending lectures, bird-watching walks and speaker panels, we got a glimpse into the local community, the precious local ecosystem and the history of Cape May and the surrounding area. This invaluable experience enabled us to contextualize our recommendations and tailor them to the unique and beautiful city.

The community atmosphere and love for the local area was evident in the hospitality shown to us, the tours people provided us on their days off and the palpable excitement to be hosting students with new ideas for the city.

To inform our recommendations, we were able to tour the desalination plant, see decommissioned RO filters up close and ask an abundance of questions. By seeing the desalination operations up close, we were able to reiterate the importance of a turbidity monitor, understand the current solar installations to a greater extent, and inform recommendations for further solar installations. After speaking with local residents including a member of the Environmental Commission, the Mayor, the Desalination Plant Operations team and many others, including commercial fishermen and local wildlife scientists, we were able to better understand the need for the community to be part of the change, such as by way of conservation education measures and driving key conversations on potable water desalination and local environmental needs.

Learnings from the trip will be interspersed throughout the Strategic Recommendations section.

Circular Water Solutions

4.1. Background

The Circularity Team's mission is to apply circularity principles to Cape May's potable water supply processes. McKinsey & Company define circularity as "practices that optimize resource use and minimize waste across the entire production and consumption cycle" (McKinsey & Company, 2024).

4.1.1. Overview Of Water Intake

Under current conditions, the Plant utilizes three wells to extract water from two aquifers and process it for city residents. One well draws water from the Kirkwood-Cohansey Aquifer, a freshwater aquifer. Water from this aquifer only requires chlorination before it is provided to Cape May residents. Two wells draw water from the Atlantic City 800-foot sand aquifer, a brackish aquifer that requires desalination to provide potable water to Cape May residents. During the site visit, we learned that on an annual basis, one-third of the water supply is sourced from the Kirkwood-Cohansey Aquifer while two-thirds is sourced from the Atlantic City 800-foot sand aquifer.

4.1.2. Desalination Efficiency & Concentrate Characteristics

Approximately 75% of the brackish water that is extracted from the Atlantic City 800-foot sand aquifer and subsequently desalinated becomes potable water. The remaining water contains a higher-than-potable concentration of dissolved solids, including salts, minerals, and other elements, and is referred to as the Plant's "concentrate."

Annually, Cape May generates 109 million gallons of concentrate. It is approximately one-seventh the salinity of ocean water, or 0.5% salinity, in line with EPA regulations. There are three challenges to applying circularity principles to Cape May's concentrate:

1. The Plant has only analyzed the composition of dissolved solids within the framework of regulatory environmental reporting, rather than assessing what potentially valuable minerals might be present within the concentrate. Thus, other than salinity, we do not know what other valuable minerals and elements may be present within the concentrate. Therefore, financial projections for such content are intended to encourage the Plant to thoroughly analyze the concentrate's composition.

2. The commercial industry for concentrate has primarily developed around ocean water desalination, which yields much saltier concentrate. As a result, the connected commercial standards are based on this saltier ocean water concentrate. The Circularity Team thus had to scale some commercial opportunity findings to match the lower salinity of Cape May's concentrate.

3. During the site visit we learned that the Plant is engineered to pump the concentrate into a nearby creek, which eventually flows into the Atlantic Ocean. Thus, the concentrate is treated as waste. In order to leverage the concentrate for commercial opportunities, Cape May would have to re-engineer the current plant outflows and/or include provisions in the design of the new plant to effectively divert and collect the concentrate.

We hypothesize that re-using the concentrate, depending on use case, could either add new revenue streams or lower demand for potable water in the community. Below we have outlined several commercial opportunities for the city to consider. Pursuing these avenues could transform what is now considered waste into a valued resource, thus making the city's water supply system more circular.

4.2. Commercial Opportunities For Concentrate

There are several commercial opportunities for Cape May City's concentrate, depending on its characteristics.

4.2.1. Liquid Form

As a liquid, Cape May City can use the concentrate to irrigate salt-tolerant landscaping and agriculture. We strongly recommend that if Cape May City pursues this opportunity, the city focuses on hyper-local opportunities. Transporting liquids by truck is an energy intensive process as water weighs about eight pounds per gallon (Oki & Kanae, 2006). In light of this, the most efficient option would be to repurpose and expand the water infrastructure to deliver concentrate to landscaping or agricultural clients. The most stable material for transporting concentrate is plastic pipes that are pressure sealed (W. Meyer, personal communication, April 9, 2025).

In order to successfully irrigate with concentrate, landscapers must monitor the salt concentration in soil. If salt accumulates in the soil to the point of 1% salinity, nutrient uptake in plants will be impacted. To remedy this issue, gypsum can be applied to leach sodium or the soil may be flushed with freshwater — with six inches of water leaching 50% of salt (Daniel, 2020). Luckily, Cape May City has some regional advantages. Since it is a coastal city with sandy soil, salt could naturally filter through the soil more easily that it does in clay soil. Also, many of the city's indigenous plants have a salt tolerance threshold for which 0.5% salinity is not an issue. Some recommended species are listed in the expert interview in the appendix. Nevertheless, we strongly recommend regular monitoring of the salt content of the soil.

The potential value of irrigating with concentrate can be measured in two ways: By offsetting demand, or by generating revenue. These are discussed in depth in the subsequent section.

4.2.1.1. Offsetting Demand

Within Cape May City, offsetting demand is the best way to measure the value of irrigating with concentrate. In 2024, the city consumed 64.3 million gallons of potable water for irrigation purposes. Out of 790 private entities, five businesses generated 8% of that demand. Once we calculated the city's total irrigation demand in 2024, we also determined that Cape May City is the second highest consumer of potable water for irrigation at 1.2 million gallons per year. Were Cape May City and these five private businesses to replace their landscaping with salt-tolerant plants and irrigate with concentrate, it would reduce city-wide demand for potable water by 6.2 million gallons annually. A breakdown of water consumption by entity is detailed in the table below.

Table 1: The Six Largest Consumers Of Potable Water For Irrigation In Cape May Based On 2024 Consumption
Created by Authors, Data Source: Cape May City Water & Sewer Department

Entity	Sector	2024 Potable Water Consumption (gal)
200 Congress Place (hotel)	Private	2,335,000
City of Cape May	Public	1,174,515
201 Beach Ave (condos)	Private	1,007,583
Meadows at Cape Island (management company)	Private	623,263
1205 Beach Ave (condos)	Private	550,450
1 Harbor Cove (management company)	Private	512,103
Total		6,217,914

4.2.1.2. Generating Revenue

In order to generate revenue from concentrate, Cape May would have to sell it to neighboring communities. One of the largest consumers of potable water for irrigation within Cape May City's immediate proximity is the Cape May National Golf Club in Lower Township. Currently, the golf course is permitted by the New Jersey Department of Environmental Protection to use 44 million gallons of water per year from the Kirkwood-Cohansey aquifer to irrigate 65 acres of landscaping (Lacombe et al., 2009). Assuming that the golf course would use a two inch commercial meter, Cape May would generate $140,000 in revenue — using Lower Township's water rates — to supply 44 million gallons of concentrate annually to the golf course (LTMUA Schedule of Fees Resolution No. 157-2022, 2022). As we learned during the site visit, connecting to Lower Township's water infrastructure is an extremely costly process. Given how minimal the revenue is, selling concentrate to the golf course would not be a profitable opportunity.

Therefore, the value of the concentrate is better measured by offsetting demand for potable water. Furthermore, if Cape May City irrigated all landscaping within the city with concentrate, it would offset demand for 20 million more gallons of water than the golf course.

4.2.2. Solid Form

4.2.2.1. Salt

4.2.2.1.1. Applications

Cape May's concentrate, when processed, could yield industrial-grade salt with applications spanning a variety of markets. Actual mineral content and capacity for evaporation would impact the viability of the solutions below:

- Road de-icing and snow control: The largest and most consistent market. Municipalities and private contractors buy bulk rock salt to treat roads, parking lots and walkways in winter. While demand peaks between November to March, the connected contracts are often year-round, offering revenue stability.
- Water softening systems: Homes and commercial facilities use salt pellets to regenerate ion-exchange resins in water softeners, which remove calcium and magnesium ions — the minerals that cause water hardness. This market demands clean, high-purity salt and provides consistent year-round revenue.
- Industrial brine applications: Construction and mining operations apply salt solutions to suppress road dust and stabilize soil. A niche but valuable market, especially in warmer months when de-icing demand drops.

4.2.2.1.2. Revenue Generation Opportunities

Salt recovered from the concentrate can be sold as industrial-grade salt, with two pricing tiers:

- $165/ton for post-evaporation solar salt (retail/culinary potential). Solar salt is made by using the sun and wind to evaporate water from salty brine. As the water disappears, salt crystals form and are collected. This process is natural, energy-efficient, and often used to create high-purity salt for use in food, water softening, and de-icing.

With 109 million gallons of concentrate annually and conservative extraction yields, the plant could generate tens to hundreds of thousands of dollars in annual revenue depending on recovery rates and product grade.

Based on some preliminary calculations, we determined that there is a high barrier to entering this market. The concentrate would need to be evaporated to isolate minerals prior to sales, requiring new facilities. Furthermore, the salt content of the concentrate that the current plant yields is not high enough for the industry-standard method of extraction by evaporation ponds to yield a profitable volume of salt. Our calculations showed that 1M gallons of concentrate evaporated during the summer over one acre at 10-15 cm deep would yield 19 tons of salt. By then scaling these calculations to the total volume of concentrate generated, we calculated a total yield of about 2000 tons of salt annually. Although the market value of $165/ton would yield a hefty $330,000 benefit, the land intensity, personnel cost and construction involved in building and maintaining evaporation ponds likely outweighs this benefit. In addition, the City may not want to take on the role of salt producer, and there is no market for pre-evaporation brine at the lower concentration that the current plant produces.

4.2.2.2. Minerals And Elements

Mineral and rare earth element extraction from desalination plant concentrate represents a potentially valuable revenue stream for a plant like Cape May's. While an aquifer's mineral and elemental content may vary significantly from place to place, some may be rich in dissolved elements such as magnesium, calcium, lithium, and boron. To note, however, is that the extraction processes for such elements can differ significantly from one to another, with some being quite costly.

Our research identified one case study in particular as the most useful proxy for assessing the potential value of Cape May's concentrate. This 2023 study (Villar et al., 2023) analyzed the quantities and connected value of various elements within the concentrate of nine desalination plants located in different parts of Spain. The study is particularly useful as a proxy in that one of the plants that it analyzes is a brackish water desalination plant. It is important to note that, while much research has been conducted on the elemental content of seawater desalination plant concentrate, significantly less attention has been paid to that of brackish water desalination plants. The study's analysis of the brackish desalination plant concentrate yielded the following results:

Table 2: Value Breakdown By Element
Source: (Villar et al., 2023)

	Elements	Total capacity (kg/year)	Potencial (kg/year)(60%)	Value (€)	
				Lowest	Highest
Brackish underground resources	Boron	95.8	57.48	43,381	54,226
	Calcium	31,080,000	18,648,000	8,092,528	35,184,906
	Strontium	800	480	4,754,717	27,169,811
	Magnesium	31,600,000	18,960,000	58,387,601	58,387,601
	Sodium	210,000,000	126,000,000	84,905,660	254,716,981
	Lithium	40	24	9,185,984	9,865,229
	Rubidium	10.64	6384	60,226,415	77,433,962
	Gallium	4	2.4	4,075,472	4,188,679
	Total	273,630,440	164,178,264	229,671,758	467,001,396

When adjusting these results to reflect the rate of exchange and differences in the quantity of concentrate produced between the Spanish desalination plant and that of Cape May, we found a potential value range for the elements in the concentrate of $27,082,548 - $166,661,835 USD. It is important to note a couple of key assumptions:

- The range was calculated using the low end of the study's values.
- The Spanish brackish water desalination plant produces 2.6 to 16 times more concentrate than Cape May's desalination plant. This is the reason that the potential value is still presented as a range despite using only one end of the potential value asserted by the study.
- The study assumes a 60% recovery rate by the element extraction processes.
- Due to the differences in the efficiency of the extraction processes for different minerals and elements, we decided that framing the value in terms of its total potential value would be most useful. Thus, we adjusted our calculations to reflect a 100% recovery rate.

While these figures clearly indicate a significant potential revenue stream, it is important to recognize that the mineral and elemental content of the aquifers in Spain may well differ from that of Cape May. Targeted testing of concentrate for valuable mineral contents would be needed to ascertain whether recovery would be financially viable.

Moreover, the study focuses primarily on calculating the value of the elements present in the concentrate, and does not address the potential costs of extraction. Nonetheless, this study offers valuable insight into the potential value of brackish water desalination plant concentrate.

4.2.2.2.1. Necessary Processing

In the case studies found in the literature, there are examples of several valuable minerals recovered from concentrate through different technologies. For purposes of this section, we are highlighting three elements in particular.

- **Lithium:** Lithium has been extracted from concentrate with 95% efficiency. To note, moreover, is that lithium represents one of the elements that was found more abundantly in the concentrate of the brackish water desalination plant in Spain than that of the seawater desalination plants (Fernández-Escalante et al, 2023).
- **Magnesium:** Magnesium has been extracted from concentrate with 95% efficiency using the processes of precipitation/crystallization (Fontana et al, 2022).
- **Calcium:** A brackish water treatment facility in Southern California has been economically producing calcium carbonate pellets economically as of 2017 (Paxton, 2017).

4.2.2.2.2. Applications

Minerals and elements such as the above are useful for a wide variety of applications. Calcium carbonate pellets may be used as a soil additive in agriculture to neutralize acidity and improve nutrient absorption, and may also be used in water treatment for pH and alkalinity adjustment. Lithium is currently the element in greatest demand due to its importance for electric vehicle batteries. However, for some elements such as magnesium, the applications differ significantly depending on the exact chemical compound, such as magnesium chloride versus magnesium oxide, that is being produced. Altogether, these elements are essential to many industries such as electronics manufacturing, agriculture, and renewable energy.

Circularity Recommendations

We recommend that Cape May proceed with a chemical analysis of the Plant's concentrate to identify its specific mineral and elemental composition. However, for the time being, our research indicates that the best use of the concentrate is for irrigating landscaping on city-owned properties. This approach would offset demand for potable water for irrigation by 1 million gallons per year, while setting an excellent example for the city's residents. As stated earlier, if Cape May City required its top consumers of potable water for irrigation to use concentrate, it would reduce consumption of fresh water by another 5 million gallons annually. This solution would also not necessitate the construction and maintenance of an evaporation facility.

Desalination Operations

5.1. Existing Facility Overview

Cape May's current desalination facility is the source of the city's drinking water supply, and is particularly critical during peak summer months when demand surges. According to data provided by the city, this BWRO plant currently runs three Reverse Osmosis (RO) skids each feeding approximately 1000 gallons per minute (GPM) of brackish water. The Cape May's desalination plant produces approximately 1.2 million gallons of water per day (MGD), and can surge to 2.8 MGD during peak season demand. The engineers designing the new plant informed us that at the current plant's end of life, day-to day operations achieve roughly 68% overall recovery, leaving approximately 32% of feed to become concentrate, as opposed to the standard 75/25 ratio, The system is built around RO treatment process without a formal pretreatment stage, a practice which places additional operational demand on the RO membranes (US Department of Energy, 2013). After the RO stage, permeate (potable) water undergoes post-treatment via lime slurry and CO2 dosing before being distributed to customers.

To mitigate silica scaling within the RO membranes, the plant administers anti-scalant. However, current dosing levels are intentionally lower than industry best practices. This underdosing is a strategic decision based upon an operational trade-off, balancing cost containment with acceptable levels of performance degradation. Despite these constraints, the system demonstrates commendable output efficiency, especially in summer when water production peaks at over 69 million gallons monthly.

Electrical energy is, according to the literature, the largest expense in desalination. For this reason, and because Cape May's negotiated electrical rates have been subject to increase in recent years, the analysis has also focused on energy sourcing and energy efficiency in plant operations.

Nonetheless, the absence of pretreatment and suboptimal chemical dosing pose long-term risks to membrane lifespan and maintenance frequency, indicating key areas for optimization as the city evaluates future desalination investments.

5.2. Recommendations For Efficiency Gains

5.2.1. Inline Turbidity Meters

Inline turbidity meters, also known as turbidity sensors or monitors, are instruments that continuously measure the cloudiness or haziness of water, which reflects the concentration of suspended particles. Turbidity is a key quality parameter in desalination operations, as elevated levels of suspended solids can damage sensitive equipment, especially the RO membranes, by causing fouling, abrasion, and decreased filtration efficiency (Philibert et al., 2024). Monitoring turbidity helps protect membrane lifespan and maintain consistent system performance (Alsarayeh, A et al., 2020)..

Currently, Cape May's desalination plant does not employ inline turbidity meters at the intake points of its production wells. Instead, operators rely on a manual flushing protocol; after initiating the well pump, water is diverted for a typically 10 minutes to an external discharge point. This pre-flush is meant to clear out turbid water before directing flow to the treatment train. However, without real-time feedback, this time-based method results in a huge amount of unnecessary water loss or delay throughout.

The integration of inline turbidity meters in Cape May's planned new desalination plant offers a strategic opportunity to improve operational efficiency. By providing continuous, real-time turbidity readings, these sensors allow operators to determine precisely when source water quality meets intake standards. As a result, flushing durations can be shortened dynamically, optimizing both energy use and raw water conservation. In addition to operational benefits, real-time monitoring enhances the facility's responsiveness to changing water source conditions — particularly valuable in Cape May's coastal environment (Martinez Paz et al., 2021).

5.2.2. Energy Recovery Technologies

Energy Recovery Devices (ERDs) are technologies designed specifically for reverse osmosis desalination plants, used to capture and then reuse hydraulic energy from high-pressure concentrate. During the desalination process, the feedwater is pumped and pressurized in order to force the incoming water through semi-permeable membranes, which filter out salts and other unwanted minerals and compounds. This process creates a high-pressure stream of concentrate, also known as to referred to as brine discharge, which is typically wasted hydraulic energy (Alsarayreh et al., 2020). Energy ERDs of all varieties capture and reuse this hydraulic energy by transferring the hydraulic pressure from the outgoing brine discharge into the incoming feedwater, which reclaims lost energy. The intervention of an ERD reduces overall energy demands, and therefore enhances the energy and economic efficiency of the desalination operation (Energy Recovery Inc., 2024).

Depending on the type of ERD implemented at either a brackish water reverse osmosis plant (BWRO) or sea water reverse osmosis plant (SWRO), the efficiency of the hydraulic energy recovery can range from 70-98% (ERI, 2025; Energy Recovery Inc., 2024). This positively impacts the overall energy efficiency of the desalination plant by reducing specific energy consumption (SEC) based upon the volume of potable water produced by approximately 10–30% at BWRO plants. The range of efficiency depends upon the scale of the system, salinity of the feedwater, and operational conditions (Energy Recovery Inc., 2024; Alsarayreh et al., 2020)

Pumping accounts for the majority of electricity use in brackish-RO plants (Pearson et al., 2021). Analyses of U.S. municipal BWRO facilities show that high-pressure and booster pumps typically consume about 55 -70 % of total plant kWh (Ghaffour et al., 2013). Because ERDs act directly on that pump load, even what appears to be a modest percentage reduction in SEC translates into a significant share of overall plant savings. Additionally, ERDs help the operations of the plant run more smoothly by minimizing stress on the machinery such as the pumps and membranes (Ghaffour et al., 2013). ERDs have the capability to decrease GHG produced from the operations of the plant, and can support broader sustainability and compliance goals for municipalities.

5.2.3. Classification Of Energy Recovery Devices

There are three categories of ERDs: Isobaric, Centrifugal, and Positive Displacement Devices. Given the scope and goals for Cape May's BWRO plant, we focused on an Isobaric device called the Pressure Exchanger (PX), and a Centrifugal device called the Turbocharger. These two types of ERDs were selected due to their proven efficiencies, popularity, and current use in municipal-scale desalination. Other ERDs such as DWEER (Dual Work Exchanger Energy Recovery), Pelton Wheel turbines, and Hydraulic Pressure Boosters exist but are less commonly used today due to factors such as complexity, maintenance requirements, and lower efficiencies (Ghaffour et al., 2013; Littrell et al., 2022).

Table 3: PX vs. Turbocharger Key Performance Metrics
Created by Authors, Sources: Alsarayreh et al. (2020); Energy Recovery Inc. (2024); FEDCO (n.d.); Littrell et al. (2022)

ERD Type	Device	Efficiency Range	SEC Reduction	Implementation Considerations
Isobaric	Pressure Exchanger	95%-98%	~15%-30%	• Higher complexity • Higher upfront costs • Suitable for variable conditions and larger scale plants
Centrifugal	Turbocharger	70%-80%	~10%-20%	• Lower complexity • Lower upfront costs • Ideal for stable conditions and smaller-scale plants

Isobaric Devices

Pressure Exchangers (PX) are a widely used and highly efficient type of isobaric ERD, known for their ability to directly transfer pressure from the brine to the incoming feedwater with minimal energy loss. These devices typically achieve very high efficiencies between 95% and 98%, minimizing energy losses and maintaining efficiency across varying operational conditions (Energy Recovery Inc., 2024; Littrell et al., 2022). Isobaric units are typically preferred for large-scale SWRO systems or BWRO plants where the energy efficiency gain justifies higher upfront costs, as PXs require a variable frequency drive (VFD) and booster pump for its operations (Littrell et al., 2022).

Centrifugal/Turbo-based Devices

Turbochargers convert hydraulic energy into mechanical energy via turbines driven by high-pressure brine, subsequently boosting pressure in incoming feedwater. Turbochargers typically exhibit efficiencies between 70% and 85%, with peak efficiency around 80% under stable conditions (FEDCO, n.d.). While their efficiency can decline under variable conditions, their lower complexity, lower upfront investment, and ease of integration make turbochargers particularly attractive for small to medium scale BWRO systems or applications with moderate energy recovery requirements (FEDCO, n.d.; ERI, 2025).

Comparative Insights

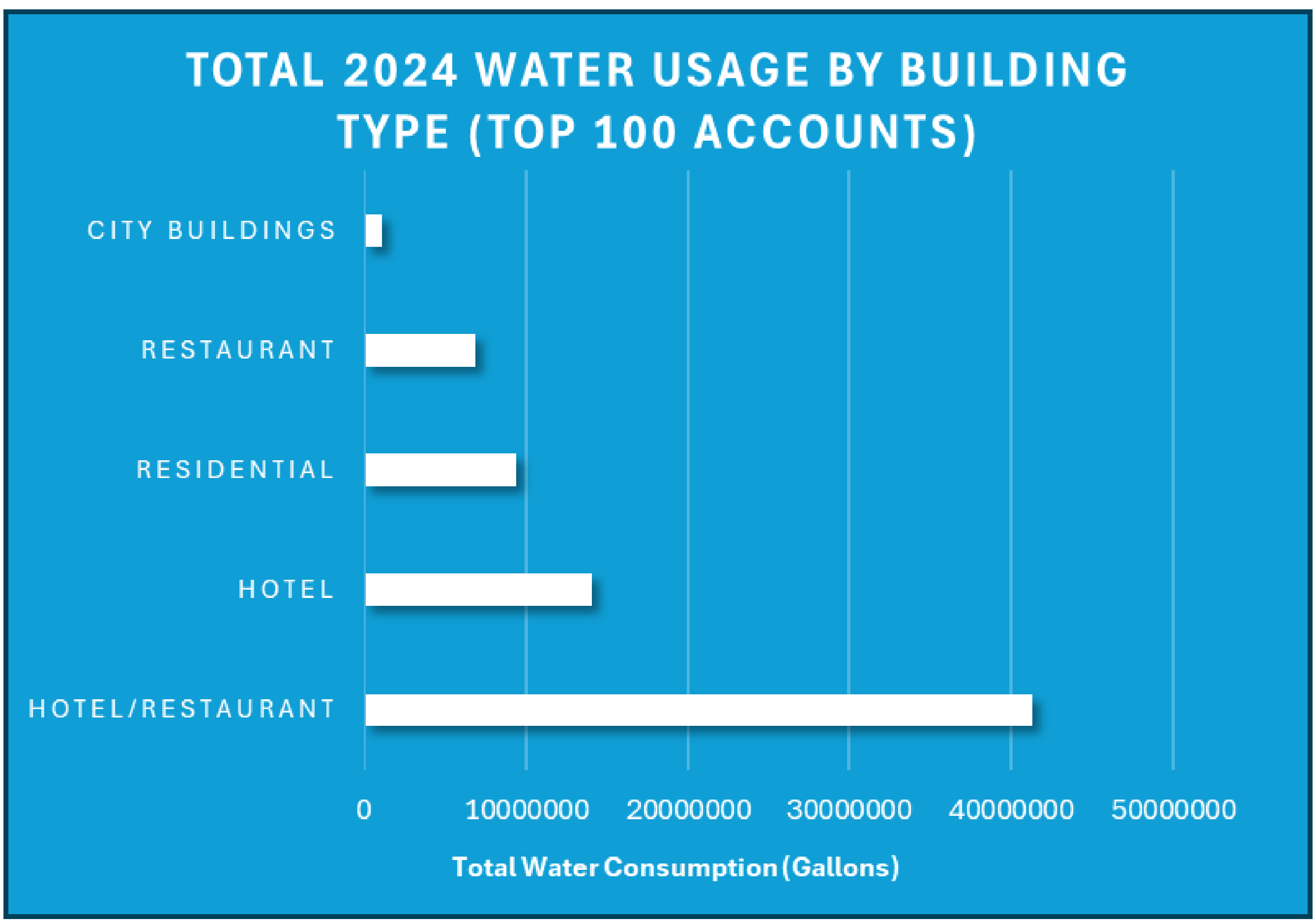
Our review points to practical trade-offs between the turbocharger and PX . Turbochargers give us a simpler, and reportedly lower-cost way to recover energy, particularly when the plant runs under steady conditions. Meanwhile PX delivers higher efficiencies and operates at high efficiency even with variable salinity or flow changes, albeit with more capital and integration effort. Because both devices assist the pumps, even a 10% drop in SEC translates into noticeable cuts in the monthly electric bill. Our team explores the financial feasibility of the PX for Cape May City, given that the city currently plans to integrate turbochargers into its next desalination plant. Cape May City is in a unique position to design it's next facility with PX technology now, allowing it to incorporate the operational infrastructure needed for PX technology, rather than navigate a retrofit later.

Water
Demand

6.1. Water Usage Analysis

We conducted an analysis of the water usage in Cape May City assessing who are the largest water consumers. This analysis was done by taking 2024 water usage data provided by the Cape May City Water & Sewer Department and sorting the list from highest to lowest usage. The top 100 accounts were categorized as hotel/restaurant, hotel, residential, restaurant, and city buildings. Building types were determined by searching the addresses via google maps. Note that hotel/restaurant refers to any hotel that additionally contains a restaurant (as many of the large-scale hotels near the beach do). Figure 5 shows the results of this analysis.

Figure 5: Total 2024 Water Usage By Building Type
Created by Authors, Data Source: Cape May City Water & Sewer Department



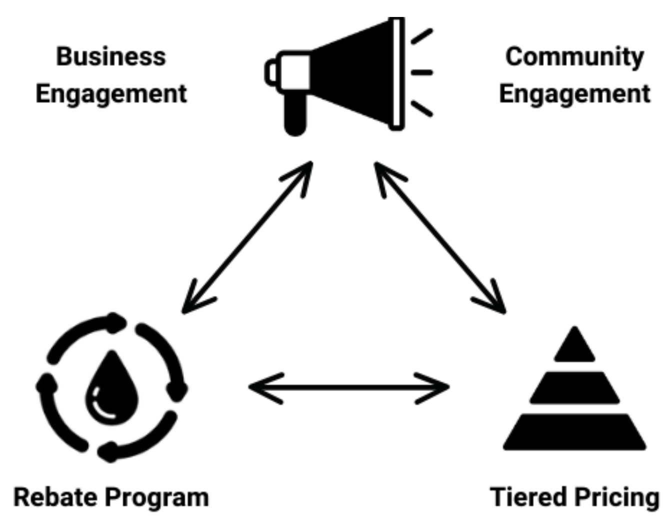
The main takeaway is that the hotel/restaurant establishments are by far the largest consumers. These are generally the large-scale hotels on Beach Avenue. The hotel/restaurant terminology may be misleading as it could suggest that for these establishments specifically, the hotel operations and restaurant operations consume an equal amount of water. However, the hotel aspect generally occupies the large majority of the building and in all likelihood, hotel operations consume significantly more water than the restaurant operations. For that reason, we consider hotels alone as the largest water consumers in Cape May City. Many of our recommendations in the later sections of this report are catered specifically towards hotels; however, conducting a water audit in these buildings would help guide recommendations in the future. Our results also indicate that no AirBnB rentals appeared in the top 100 accounts, although it is possible that the cumulative water consumption of AirBnB is significant. Here, too, water audits would help to determine whether the water use per capita values of AirBnB warrant targeted intervention, and how they compare to hotel or residential per capita usage.

This analysis provides a reliable sample size as to how and where water conservation initiatives might be initially focused. In the sections below, we will be discussing a variety of recommendations for water conservation in Cape May City. We recommend Cape May City to initially focus conservation efforts on these hotels. Implementation of conservation initiatives may become complex when trying to account for all types of water consumers (residential and commercial). Focusing on hotels could help mitigate this complexity while still directing water conservation initiatives at the target audience. For example, Cape May City might pilot a rebate program for water-efficient appliances only for hotels and then expand the program in years to come. In the sections below, we will dive into more detail on our recommended initiatives and how they could be strategically implemented to optimize the water demand reduction outcome for Cape May City.

6.2. Water Conservation Proposal: Proposed Initiatives

As the desalination plant approaches its end of life, the risk of system breakdowns may increase. For that reason, managing the water demand of Cape May City (especially during peak season) is critical. This section will discuss our water conservation proposal that aims not only to reduce water demand but also to educate the community on their water supply and the importance of water conservation. Our water conservation proposal has three main initiatives. This includes engagement, rebates (incentivizing water-efficient technology) and tiered pricing. Rebates serve as the initiative that may incentivize water conservation while the tiered pricing initiative may disincentivize excessive water consumption.The engagement initiative aims to reinforce these two initiatives and could also educate businesses and the community on the importance of water conservation. We will discuss each of these initiatives in greater detail in Section 6.4, 6.5 and 6.6.

Figure 6: Water Conservation Proposal, Three Pronged Approach
Created by Authors



While each initiative could be effective on its own, strategically utilizing all three to reinforce the other initiatives may create a more holistic approach to water conservation. As an example, if businesses are aware of incoming water pricing changes, they may be more likely to use the rebate program to install water efficient appliances. Conversely, providing a rebate program may help prepare businesses for a tiered pricing system. Engagement could enhance both of these initiatives while also creating a more water-conscious community. Engagement is the piece of the puzzle that might encourage businesses and the community to take advantage of the rebate program prior to implementation of tiered pricing. In addition, engagement may also spread awareness of the importance of water conservation especially as it relates to the details of Cape May City's complex water infrastructure. In Section 6.3, we will be discussing a strategic order of implementation that could optimize the effectiveness of each initiative.

6.3. Suggested Timeline Proposal

Developing a strategy to space out the implementation of these initiatives over time could enhance their effectiveness. Timing and sequence also plays an important role in how these changes may be perceived. Especially as it relates to tiered pricing, allowing time for the community and businesses to provide their input and prepare for change reduces the risk of disapproval.

Figure 7 illustrates our suggested implementation timeline. We will also discuss each phase of this timeline in more detail below Figure 7.

Figure 7: Suggested Implementation Timeline
Created by Authors

Phase 1: Preparation

The goal of this phase is to lay the groundwork for a longer-term water conservation plan. In this phase, it is important to conduct additional water usage assessments to gain a more comprehensive understanding of the areas with the greatest conservation potential. Consider who are the key stakeholders and set engagement plans for each stakeholder group. Once this stakeholder mapping is complete and policy priorities established, the city can initiate drafting plans for tiered pricing as well as the rebate program, then review all of these within city governance practices. For reasons previously mentioned, a pilot program with large-scale hotels for the rebate program could be an early test case. Identifying the funding sources for the rebate program and developing key performance indicators, both quantitative and qualitative metrics to define success for this plan, are part of this phase.

The Environmental Protection Agency's WaterSense program, which certifies the "gold standard" for water-efficient products, has an abundance of resources for water efficiency in commercial buildings (EPA, 2016). This includes guides on planning and outreach that help explain how to make the business case to various types of businesses. We will discuss these guidelines in the later sections of this report, however, we highly recommend utilizing WaterSense's resources.

Phase 2: Engagement

The goal of this phase is to build awareness, buy-in and trust with all key stakeholder groups. First, the city government can help the Cape May City community understand the urgency of the situation. With a better understanding on why these changes are occurring, the community may feel a stronger sense of motivation to reduce their consumption. This could be anticipated to also positively impact how the tiered pricing system is received. After that, advocates can spread the word on tiered pricing and the rebate program through newspapers, social media or any other effective platforms (e.g., in-person community events). Table 6 has more details to help the city plan for what it might expect from journalistic inquiries and how to prepare to answer them in order to set a positive outlook for the program. Coordinating workshops with businesses can help to strategize water conservation strategies such as towel/linen reuse programs or conservation reminders on mirrors. Utilizing town halls to gather concerns or feedback from the community can increase transparency and inclusivity. Using that feedback, the city can adjust any proposed tiered pricing system and rebate program to meet business/community preferences and needs.

Phase 3: Rebate Program Rollout

This phase would mark the first test bed for the adoption of water-efficient technologies. Ensure the criteria for receiving a rebate is set and the application process is ready to go. Provide guidance and support for the target audience of the rebate program (primarily large-scale hotels).

During initial implementation of the rebate program, consider incentivizing water-efficient technology adoption by offering larger rebates earlier on. For example, if a hotel replaces their showerheads prior to July 1st, they receive a full rebate of $30 per showerhead. If replacement occurs after July 1st, they receive $15 per showerhead. Singapore's government demonstrated success with this approach as they were transitioning to a new electronic road pricing system that necessitated vehicle upgrades (OneMotoring, 2025). This system may accelerate adoption of water-efficient technologies and help consumers prepare for the tiered pricing rollout.

Phase 4: Tiered Pricing Rollout

The goal of this phase is to successfully encourage water conservation through tiered and equitable pricing. Using feedback from the engagement phase, finalize the tiered pricing system. Continue holding town hall meetings to explain the system and its rationale. Provide user friendly resources, such as a redesigned water bill (see Figure 11), to the community that explain the rate structure (e.g. example water bills for residents and commercial buildings). Ensure the rebate program is still being advertised to help in adjusting to this phase.

Phase 5: Measuring And Adjusting

The goal of this phase is to track progress and make improvements. Continue reviewing the quarterly usage data to track successful reductions. Measure the rebate program uptake along with revenue stability from tiered pricing. Send out surveys to assess the public opinion on tiered pricing and the rebate program. Make adjustments for these initiatives based on the feedback received or analyses findings. Lastly, be transparent about progress to the public. Publish successful reductions in water conservation that have occurred throughout this period.

Engagement, rebates and tiered pricing will be discussed in greater detail in Sections 6.4, 6.5 and 6.6, respectively.

6.4. Engagement

Following the exploration of infrastructure and pricing reforms, this section introduces the second pillar of our water conservation proposal: education and engagement. The team recognises that infrastructure alone cannot achieve Cape May's long-term water sustainability goals, effective public engagement across all user groups is essential. This section examines strategies to promote water conservation behavior through targeted outreach and behavioral interventions. It begins with exploring methods to influence water conservation among both permanent residents and temporary visitors, by deploying proven behavioral nudges. Furthermore, this section looks into engaging the business and hospitality sectors whose high water use during peak tourist season offers significant opportunities for impact. It then evaluates patterns of water consumption across different business types to identify priority targets for conservation initiatives. Finally, it highlights the role of broader community engagement efforts in cultivating a culture of water stewardship across Cape May City. Together, these initiatives aim to foster lasting behavioral change that complements technical and pricing solutions.

6.4.1. Influencing Water Conservation Among Permanent Residents

Currently, many members of the Cape May community have not been educated on where their water comes from, mostly due to lack of opportunities to learn about the public water system. During our visit to Cape May, we had the pleasure of meeting and speaking with many locals in restaurants, stores, and other public spaces. When we shared that we were here working with the public water system and the desalination plant, we were principally met with two reactions: surprise at learning that there is a desalination facility in their city, and concern over the potential increase of water costs.

For tiered pricing and broader water conservation efforts to succeed, especially among permanent residents, a community-centered approach is essential. Education campaigns, clear communication, and open channels for discussion may well be key. Residents need spaces to learn, ask questions, voice concerns, and share feedback on water-related topics and pricing policies.

For the educational campaign, we are focused on a holistic approach that centers the Cape May community. The goal is to make learning about water conservation easy and highly accessible. We aim to do this by creating opportunities, engaging children, and sharing information in public spaces.

Grounded in the theory of trickle-up education, which suggests that knowledge and habits instilled in children can influence their families and communities, we propose an initiative to build water awareness in permanent residents through school-based programs (Slungaard Mumma, 2023). By integrating structured educational efforts into Cape May's schools, we anticipate long-term, citywide improvements in water conservation practices (Iwasaki, 2022).

Table 4: Proposed Educational Programs
Created by Authors

Elementary and Middle School Curriculum	Junior High and High School Curriculum - LCMR
1. Understanding water and the water cycle 2. Recognizing the importance of water and its critical uses Suggested activity: journaling and logging daily water use 3. Addressing water scarcity and conservation strategies 4. Exploring the history of water in Cape May 5. Field trip to the Cape May desalination site (only accessing areas that are safe for the children)	1. In-depth analysis of water usage and critical applications 2. Water scarcity challenges and conservation strategies 3. Historical perspective on water management in Cape May 4. Field Trip to the Cape May desalination plant
Follow-up activity: • Designing posters for public awareness campaigns	Follow-up activity: • Selecting posters designed for public awareness campaign • Identifying optimal locations for public educational signage • Collaboration between school newspaper and Exit Zero, the local newspaper, on the source and operations of water supply in Cape May

Figure 8: Mock-Up Of School Collaboration - Public Awareness Campaigns
Created by Authors, Image Source: Google Maps Street View

**Please note: These are not the signs suggested for the campaign, but meant to illustrate what the student's signs might look like displayed throughout the city*

Beyond school-based initiatives, water awareness can be extended to Cape May residents through "Open Door Days" at the desalination facility. Inspired by successful programs in cities like Toronto, this initiative would allow residents and visitors to tour the facility, turning it into a kind of "living museum" in line with Cape May's tradition of honoring its history through museums (City of Toronto, n.d.). This would highlight both the heritage, history, and current innovation behind the city's water systems.

Together with student-designed posters for a public awareness campaign, and collaboration with *Exit Zero*, Cape May's Local Paper these efforts would help tell the story of Cape May's water and foster a culture of conservation and shared responsibility.

Once residents are informed about the city's water systems and policies, they need ongoing opportunities to engage. As mentioned in the implementation plan, regular open communication and online forums can give the community a space to ask questions, raise concerns, and provide feedback to collaborate on improving water demand practices citywide.

6.4.2. Influencing Water Conservation Among Temporary Residents

Encouraging water conservation among short-term visitors poses a unique challenge, given the lack of long-term accountability. However, behavioral interventions rooted in psychology, such as clear signs outlining collaborative efforts and reminders near mirrors, have been identified as a low-cost, high-impact opportunity for the City of Cape May. Water usage data analysis covered in Section 6.1 clearly indicates that hotels are among the most water-intensive users, making them a critical intervention point. Hospitality providers especially those operating during peak summer tourist months should be encouraged or mandated to adopt targeted conservation strategies that promote mindful water use without compromising guest satisfaction.

Furthermore, studies have shown that placing signs near mirrors can be especially effective, especially in high water use areas such as bathrooms. When individuals see their reflection while reading conservation prompts, they are more likely to behave in alignment with moral and social expectations (Well, 2020).

Moreover, messaging that reminds guests of desired behaviours and the environmental consequences of excessive water use has been proven to boost compliance and can lead to measurable reductions in usage (Zhao et al., 2023). Hospitality providers should be encouraged to adopt these measures, which simultaneously support sustainability goals and enhance Cape May's appeal to environmentally conscious travelers.

In addition to signage, hotels can implement a suite of operational measures. These include offering guests the option to decline daily linen and towel changes, installing water-efficient fixtures, and retrofitting irrigation systems with smart controllers. Collectively, these actions help shift the burden of conservation from guests alone to the hospitality system itself.

Figure 9: Mock-Up Of Mirror Signage In Hotel Room
Created by Authors, Image Source: Canva Photos

Doing so not only aligns with Cape May's sustainability and resilience goals but also enhances the city's branding as a forward-thinking, eco-conscious tourist destination. Incentive programs and water-efficient technologies are discussed further in Section 6.5.

Table 5: Potential Water Conservation Measures In Hotels
Created by Authors

Category	Measure	Impact
Guest Engagement	Place mirror-adjacent signage on water use	Increases guest awareness and action (Stanford SPARQ, n.d.)
Guest Engagement	Offer opt-out options for daily linen/ towel changes	Reduces laundry-related water use (Han & Hyun, 2018)
Bathroom Fixtures	Install low-flow showerheads and faucet aerators	Cuts water use by 20-30% (American Hotel & Lodging Association, n.d.)
Toilet Systems	Use dual-flush or low-flow toilets	Reduces flush volume significantly (EPA, 2025; Northern Ireland Water, 2024)
Kitchen and Laundry Operations	Upgrade to ENERGY STAR-rated dishwashers and washers	Lowers water and energy consumption (EPA, 2017)
Irrigation Systems	Install smart irrigation controllers and drought-tolerant landscaping	Minimizes outdoor water usage (Bwambale et al., 2022)
Leak Detection	Implement routine leak audits and monitoring systems	Prevents unintentional waste (Snyder et al., 2024)

Figure 10: Mock-Up Of Hotel Engagement
Created by Authors

Partnering with Cape May City for Smarter Hotel Water Use

Why This Matters

Hotels play a vital role in our town's water conservation efforts. By working together, we can reduce water usage, lower utility costs, and build a more sustainable tourism economy. Here's how your hotel can start making a difference – today:

Quick Wins: Immediate, Low-Cost Actions

These steps require minimal investment but have proven results:

- Place Mirror-Adjacent Signage
  Encourage guests to conserve water while washing hands or brushing teeth
- Offer Opt-Out Options for Linen/Towel Changes
  Give guests the choice to reuse linens during their stay – reducing laundry loads
- Install Low-Flow Showerheads and Faucet Aerators
  Cut water use by 20–30% with simple fixture upgrades
- Use Dual-Flush or Low-Flow Toilets
  Significantly reduce water used per flush without impacting guest comfort

Plan Ahead: Long-Term Upgrades

These changes offer long-term savings and impact. Consider implementing during equipment replacements or renovations:

- Upgrade to ENERGY STAR Dishwashers and Washing Machines.
  Reduce water and energy use in your kitchen and laundry operations.
- Install Smart Irrigation and Drought-Tolerant Landscaping
  Minimize outdoor water consumption without compromising aesthetics.
- Conduct Routine Leak Audits
  Prevent unnecessary water waste and protect your building infrastructure.

Support from Cape May City

We're here to help. Our team can provide:

- Sample signage and messaging templates
- Promotional materials or recognition (e.g., "Green Partner" certification)

Contact Us

[Name, Email, Phone Number]
Cape May City Water/Sewer Utility

Let's work together to make your property – and our community – more water-wise!

6.4.3. Business And Hospitality Engagement

As reliable water production becomes an increasingly pressing concern, it is essential to engage the business and hospitality industry in water conservation efforts without undermining their economic contributions. These sectors, particularly large-scale hotels and resorts, are often significant water consumers due to their operational nature and the high turnover of guests. Yet, it is important to acknowledge that they also play a pivotal role in Cape May City's local economy, supporting jobs and driving tourism revenue.

Forbes has identified water stewardship as a "fundamental necessity for companies aiming to thrive in today's environmentally conscious market" (Lindhorn, 2024), emphasizing that forward-thinking water management can foster long-term success and shared value. In this context, encouraging businesses to adopt sustainable practices should recognize that water stewardship can simultaneously represent a financial burden and a competitive advantage (Hermundsdottir & Aspelund, 2021). To help mitigate upfront costs, rebate programs targeting the installation of water-efficient fixtures such as low-flow faucets, smart irrigation systems, and leak detection technologies can ease the financial transition for businesses. At the same time, companies that position themselves as environmental leaders may gain a meaningful advantage in attracting eco-conscious consumers, strengthening their brand reputation, and aligning with broader sustainability trends without compromising guest comfort or service quality (Bansal, 2024).

6.4.4. Evaluating Water Use Across Business Types

To design effective water conservation strategies, the team analyzed water consumption patterns across different business categories and found that hotels are by far the largest water users as seen in Section 6.1. This is generally attributed to their high guest turnover rates, extensive housekeeping and laundry operations, commercial kitchens, and outdoor landscaping requirements. The data highlights that hotel properties, particularly large resorts and inns with pools and spas, represent a significant opportunity for targeted conservation efforts, given their current water usage rates. While the individual water use of Airbnb or other short-term rental units is not as significant, the proliferation of such decentralized accommodations during the tourist season may still contribute meaningfully to total demand and should not be overlooked.

While the immediate focus for Cape May City should be engaging the hotel sector due to its dominant share of water use, restaurants and food-service establishments both standalone and those operating within hotels -— warrant consideration as a later phase of engagement. Although food-service businesses consume far less water than hotels in aggregate, certain operations with intensive dishwashing and kitchen activities can still drive notable usage. Once conservation initiatives are successfully implemented among major hotel properties, Cape May City can consider extending targeted outreach programs and rebate offerings to the food-service sector, leveraging billing data segmented by account type to high-usage entities within that category.

6.4.5. Building A Narrative For Public Engagement & Support

As Cape May considers implementing tiered pricing and broader water conservation strategies, building strong community support can be anticipated to be critical to success. Public engagement should be aimed to go beyond simply announcing changes, it must foster understanding and a sense of shared purpose. To achieve this, Cape May should develop a cohesive narrative that frames the need for action in ways that resonate with residents' values and aspirations.

Messaging should emphasize that water conservation is part of a larger strategy to protect the town's cherished environment such as its beaches, parks, and natural ecosystems. Residents should be encouraged to see themselves as stewards of Cape May City's future, helping ensure that the community remains a beautiful, vibrant place for generations to come. More importantly, water conservation should be framed not as a burden, but as a shared responsibility and an investment in Cape May City's long-term resilience (Li & Wang, 2024).

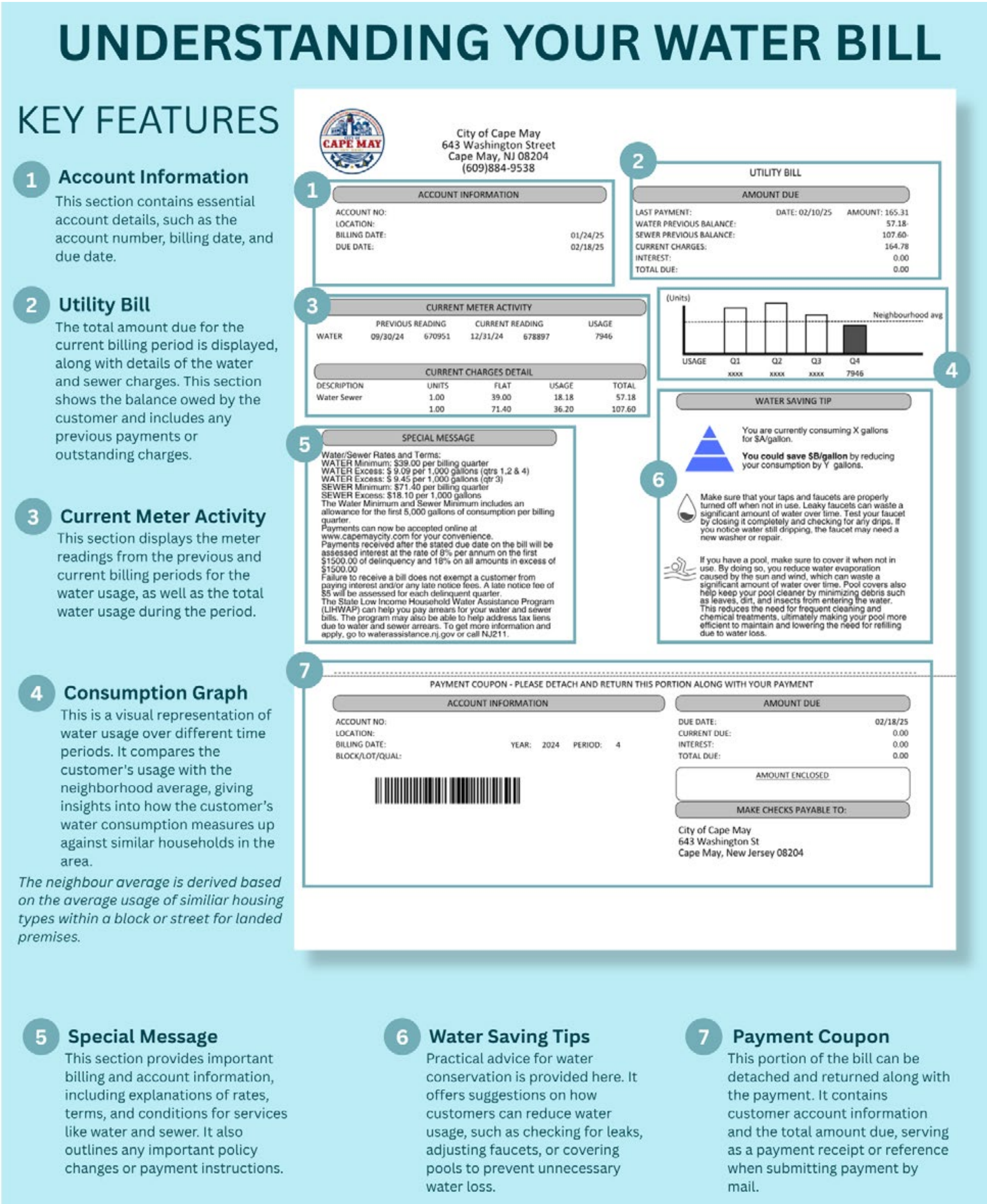
Furthermore, it is extremely important to clearly communicate the rationale behind pricing changes to water. Cape May City's water infrastructure requires continual upgrades to ensure reliable service. Revenue generated through the tiered pricing system can be reinvested into system improvements, making the city's water supply more resilient to challenges such as aging infrastructure. Furthermore, emphasize that tiered pricing reforms are a part of Cape May City's broader commitment to environmental stewardship. Protecting local natural resources requires proactive water conservation strategies, including encouraging conservation through pricing signals (EPA, 2016). Lastly, tiered pricing could be framed as a way to promote fairness where lower-use households would see little to no change in their bills, while high-usage customers pay their fair share. Making clear equity is a central consideration while introducing rebates and financial assistance programs would be intended to minimize any disproportionate burden on low-income residents.

6.4.6. Redesign Of Water Bill

Redesigning water bills is a powerful yet underutilized strategy for promoting conservation, as utility bills are one of the few regular touchpoints between water providers and residents. When designed thoughtfully, bills can do more than communicate charges - they can influence behavior. Large-scale trials have shown that incorporating behavioral science elements like personalized feedback and simplified language into water bills can significantly reduce consumption (Behavioural Insights Team, 2023). Similarly, social comparison techniques have been found to influence household utility use, leading to measurable reductions in resource consumption (Allcott, 2011).

In light of this, Cape May could consider redesigning its water bills to incorporate a behavioral dimension, such as comparative consumption feedback and tailored conservation messaging. The traditional format focused solely on technical chargers and meter readings, offering limited insight into how household usage compared with peers. In contrast, the updated design now includes a "Consumption Graph" that displays a customer's quarterly water use alongside the neighborhood average - an evidence-based intervention known to influence behavior through social norming (Lede et al., 2019).

Figure 11: Mock Up Of Redesigned Water Bill
Created by Authors



Studies in behavioral economics suggest that when individuals see they are consuming more than their peers, they are more likely to adjust their behavior to align with the perceived community standards (Frederiks et al., 2015).

This approach subtly encourages conservation by fostering a sense of accountability and competitiveness (Raj, 2024). For example, a household that notices it is using more water than its neighbors may feel motivated to investigate leaks, reduce irrigation frequency, or adopt more water-efficient fixtures. Additionally, the bill includes seasonally relevant water-saving tips such as covering pools to reduce evaporation or fixing leaky faucets, providing practical guidance that compliments the normative feedback.

The simplified layout, visual data display, and actionable recommendations not only enhance bill transparency but also create an educational touchpoint. As Cape May works toward long-term water resilience, this redesigned water utility bill represents a scalable, low-cost strategy for cultivating sustainable behavior among residents — especially when paired with broader public awareness campaigns and rebate programs.

6.4.7. Anticipating Media And Journalists' Inquiries

In the lead-up to — and following — the implementation of rebates and tiered pricing policies aimed at reducing water demand, Cape May is likely to attract attention from local media and journalists.

Below is an illustrative list of potential questions city officials may be asked, grouped into five categories: Policy & Rationale, Impact on Residents & Businesses, Implementation & Enforcement, Environmental Considerations, and Public Engagement & Feedback. These questions are speculative and not intended as a script, but rather as a tool to help anticipate and prepare for common lines of inquiry.

The goal of developing clear, positively framed responses is to suggest ways the city may craft a compelling, community-centered narrative that fosters understanding and public support for the tiered pricing system. Transparent and candid responses can help demystify the program and underscore the benefits it offers not only for Cape May City as a whole, but also for individual residents and businesses who take part in water conservation efforts.

Media conversations also present a valuable opportunity to explain the broader context of Cape May's current water challenges. They can offer a platform to highlight how this strategy was developed with local needs in mind, and to emphasize the city's commitment to ensuring the long-term sustainability of its water supply.

Preparing for journal and media engagements is a method to allow the city to present a favorable narrative which accurately portrays the importance of ensuring sustainable water supply for the city, allowing the population and the planet to thrive for years to come.

Table 6: Preparing For Media And Journalist Inquiries
Created by Authors

Category	Question	Approach
Policy & Rationale	What is the main goal of the tiered pricing structure? Is it conservation, revenue generation, or something else?	*Focus on conservation, longevity of the desalination plant and water supply, based on conservation metrics and success of different cities across the country.*
	How would this system account for the drastic seasonal population shifts in Cape May?	
	Have you studied how similar towns have implemented tiered pricing successfully?	
	Can residents expect water bills to increase?	
Impact on Residents & Businesses	What metrics will determine the different pricing tiers? Will it be based on usage brackets, property type, or another factor?	*Focus on community involvement and shared spaces for concerns and feedback throughout the implementation process. This is a living initiative that listens and grows during set metering and adjustment periods.*
	How will you ensure that landlords pass any cost savings (or avoid unnecessary cost burdens) to renters?	
	Will this require infrastructure upgrades, such as smart meters or billing system changes?	
Environmental Considerations	Do you anticipate that tiered pricing will lead to meaningful reductions in water consumption?	*Focus on research and how the program is informed by successful case studies across the nation, but adapted for the specific needs of Cape May - including transition needs.*
	How will the city measure and report on the policy's effectiveness?	
	Are there any accompanying conservation programs, such as rebates for water-efficient appliances or landscaping?	
Public Engagement & Feedback	How are you involving residents and businesses in shaping this policy?	*Focus on how the goal is to build this program with and for the community - keeping residents and businesses in mind and creating spaces for their voices and ideas to be heard.*
	Will there be a trial period or opportunities to adjust the structure based on feedback?	
	When do you expect this to be implemented, and what's the timeline for public comment?	

6.5. Rebate Program: Water Efficient Technology

As mentioned previously, Cape May City sees a high influx of seasonal residents in the warmer seasons. The large majority of this temporary population is likely not to be knowledgeable on Cape May City's water situation and also unlikely to make any extra efforts to reduce their water usage. This is where water-efficient technology becomes a critical piece of demand reduction for Cape May City. Water-efficient appliances such as low-flow toilets or showerheads help passively reduce water consumption for the temporary residents who are not actively concerned with their water usage. Various case studies occurring in Tampa and Seattle report low-flow toilets savings results from 6.1 to 10.6 gallons per capita per day. Low-flow showerheads have a range from 1.7 to 3.6 gallons per capita per day (Olmstead & Stavins, 2009). Especially for the large-scale hotels in Cape May City (labeled as hotel/restaurants in Section 6.1), there could be high potential to save water through these appliances.

The EPA's WaterSense program certifies the "gold standard" of water-efficient technologies. Any product or appliance that has a WaterSense label uses 20% less than standard models (EPA WaterSense, 2024). A variety of hotels have seen significant reductions in water consumption through installation of WaterSense labeled products (see Table 7).

Table 7: WaterSense Hotel Case Studies
Created by Authors, Information Source: (EPA WaterSense, 2024)

Case Study	Initiatives	Water Savings	Cost Savings
Hilton Palacio del Rio Hotel	Retrofits for toilets, faucets, showerheads and water-cooled ice machines	26 million gallons	$160,000 in water, sewer and energy costs per year
Holiday Inn San Antonio	Retrofits for toilets, faucets and showerheads	7 million gallons per year	$68,000 in water, sewer and energy costs per year
Olympic National Park Hotel	Retrofits for showerheads and kitchen fixtures. Education efforts for guests and employees.	1.4 million gallons of water annually	$47,000 in water and sewer costs
Westin Riverwalk Hotel in San Antonio	High-efficiency toilets and washing machine upgrades	2.2 million gallons of water per year	$20,000 in water, sewer and energy costs
Caesars Entertainment Code Green Strategy	Towel and linen reuse program, washing machine upgrades, high-efficiency showerheads, faucet aerators, xeriscaping, leak identification, dual-flush toilets	430 million gallons	$1.5 million

We recommend Cape May City to build off the demonstrated success seen in Table 7. The next section will discuss how Cape May City could incentivize hotels to upgrade to water-efficient appliances. Beyond technological upgrades, these hotels also employed educational and behavioral strategies to influence employees and guests to conserve water. Section 6.4.2 elaborates further on various guest education or hospitality strategies that Cape May City could consider. We also recommend utilizing the vast resources of the EPA's WaterSense program which covers nearly all aspects of water conservation in the hospitality industry (EPA WaterSense, 2024).

6.5.1. Incentivizing Water-Efficient Technologies: Rebates

An important piece to water-efficient technology is strategizing how to increase adoption. Many cities have established an incentive program that provides rebates for those who upgrade to water-efficient technologies. As large-scale hotels (hotel/restaurants) represent the majority of the top water consumers, we recommend establishing a pilot rebate program that initially is catered to hotels. Launching the rebate program for commercial and residential users in Cape May City is also an option, however, piloting it with hotels could simplify the process while still targeting the largest users. In this pilot program, we recommend starting with showerheads and toilets as they are large sources of water consumption in hotels. Washing machines could also be considered, however, showerheads and toilets have a lower cost barrier. To establish a general idea how much showerheads and toilets are rebated for, Table 8 provides compiled data from other city rebate programs.

Table 8: City Rebate Examples
Created by Authors, Information Source: (EPA WaterSense, n.d.)

City	Type	Showerhead Rebate Amount	Toilet Rebate Amount
Miami-Dade County, Florida	Hotel Specific	Free Showerheads	$50
Tampa Bay, Florida	Hotel Specific	$15	$40-100
Honolulu, Hawaii	Commercial	N/A	$100
Glendale, Arizona	Residential	N/A	$100
Bozeman, Montana	Residential	$10-20	$25-125 (higher rebate for higher efficiency)
JEA, Florida	Commercial	$10	$100-250 (higher rebate for higher efficiency)
Charlottesville, Virginia	Residential/Commercial	Showerhead included in free water conservation kit	$150
Lewisville, Texas	Residential	$30	$50
Bend, Oregon	Residential	Showerhead included in free water conservation kit	$80

The variety of city rebate programs points to the fact that incentivizing is an effective strategy. In the case of San Antonio, tourism is the second largest industry. Similarly to Cape May City, San Antonio sees a large seasonal population which consumes a considerable amount of water. For that reason, the San Antonio Water System created the WaterSaver Hotel program. This program includes rebates for laundry machinery along with retrofits for sanitary fixtures. The Westin Riverwalk Hotel in San Antonio utilized this program and achieved a 65% reduction in water consumption along with a $20,000 reduction in water, sewer and energy costs annually (EPA WaterSense, 2014). This example provides evidence for the efficacy of rebates and reducing water consumption in hotels. A rebate program specifically for hotels could be a key initiative to reduce overall water usage in Cape May City.

Rebate programs come in many shapes and sizes. Note that while we recommend low-flow showerheads and toilets as a low-cost starting point, Cape May City can expand the rebate program out to cover a larger variety of products and appliances. This would help make water-efficient technology accessible to other building types such as restaurants and residential households. Overall, piloting a rebate program with low-flow showerheads and toilets could serve as a simple yet effective strategy for increasing the adoption of water-efficient technologies and consequently reducing water demand in Cape May City.

6.5.2. Financial Aspects

From the perspective of the hotels, there is a strong economic benefit for becoming more water efficient. Implementing water efficient practices in commercial buildings is estimated to reduce operating costs by 11% (EPA, 2016). Table 7 also illustrates the cost savings that each case study saw. Especially if Cape May City is to implement a tiered pricing system, it is in the best economic interest of the larger scale hotels to become more water efficient. This is an important perspective to consider as Cape May City markets demand reduction initiatives to hotels. The team conducted financial analyses at the municipal and customer level. These analyses not only elaborate on cost savings for hotels and businesses but also for Cape May City's water production costs. This is explained in detail in Section 7.2.2.

6.6. Tiered Pricing

In this section, we review recommendations for two approaches to a tiered pricing system for Cape May City. The first approach discussed in Section 6.6.1 discusses a structure that covers both residential and commercial users. The priorities accounted for in this model are fairness in billing, incentivizing conservation, and aligning rates more closely with the real cost of water delivery. The second approach discussed in Section 6.6.2 provides an alternative approach to residential tiered pricing. This approach utilizes a customized approach to residential water billing based on household characteristics, such as the number of occupants. The aim with this concept is to keep water rates for essential uses low while increasing the rates for wasteful/excessive usage (e.g. lawn watering or pool filling) in a fashion that accounts for different household characteristics. Both of these approaches strive to set fair rates for users who are conscientious about their water usage while penalizing users who consume water wastefully. It should be noted that these approaches are illustrative models of how tiered pricing can reduce water usage in an equitable and fair manner. They are not direct policy recommendations, rather, conceptual frameworks to inform future discussion for Cape May City.

Cape May City currently employs a simple tiered pricing system, where customers either pay a normal rate or excess rate. While administratively simple, this approach fails to reflect the "true cost" of water production, especially given the city's reliance on energy-intensive desalination and its seasonal strain on infrastructure. True cost is a term that includes a host of factors — economic and social priorities, environmental externalities, opportunity cost — in a calculation. That true cost would be based on the community values that the city council and mayor want to reflect, but also by auditing and quantifying the other costs that the city incurs in order to furnish water — for example, funds not available for other projects or the need for water testing in streams that accept concentrate from the plant. Although not part of this report, considering the full spectrum of demands placed on the city by its water economy could help in designing a more nuanced pricing strategy.

For now, by charging similar price ranges for basic needs and discretionary use such as pool filling and excessive hotel laundry, the current model does not incentivize conservation, particularly among users such as seasonal visitors, short-term renters and the hospitality industry. Without pricing mechanisms, wasteful water usage is not penalized and no funding channel exists to reinvest in efficiency upgrades of sustainable water supply diversification. As Cape May City prepares for long-term resilience especially under climate pressures and aquifer recharge limitations, the current pricing system offers little flexibility to align water use with resource stewardship goals.

The authors examined several successful case studies of tiered water pricing policies implemented across different regions in the United States. These examples highlight how utilities have effectively used increasing block rate structures — often tailored to household-level consumption patterns — to manage water demand, respond to scarcity, and promote conservation while balancing revenue needs.

Table 9: Tiered Pricing Case Studies
Created by Authors

Location	System	Impact	Source
Aurora, Colorado	• Adopted an increasing block rate (IBR) structure with household-specific block widths • Annual adjustment of water budgets based on: individual consumption levels, water storage conditions, and revenue needs of the utility • Water rates ranged from $1.91/ thousand gallons (pre-2002) to $9.20/ thousand gallons (2004 third block). • This represents a marginal price increase of over $7/thousand gallons, nearly 5× higher for high-volume users • User classification based on volume consumption: a. Low: Bottom 25% b. Medium: Middle 50% c. High: Top 25%	Reducing total annual deliveries in 2002 and 2003 by 8 and 26%, respectively, relative to average deliveries in 2000-2001 Note from authors: As this study is over a decade old, the City of Aurora now has a more established water pricing structure, which can be found on the City's official website (look at the references: (Aurora Water, 2025) and (Aurora Water, 2024))	(Kenney et al., 2008)
Southern California	• Use household-specific IBR water budgets to help achieve the 20% reduction • Four-block system: a. Block 1: Indoor use b. Block 2: Outdoor use c. Block 3: Excessive use d. Block 4: Wasteful use • Blocks are calculated based on variables such as household size, drought factor and per-person allowance	Demand reduction of at least ~18%	Baerenklau et al., 2014)
Saratoga Spring, Utah	• Drinking water and pressurized irrigation systems are fully metered and separate • Each property has a monthly irrigation water allotment • Residential properties: 64% irrigated, 36% non-irrigated (buildings/ pavements). Allotment is ~109,000 gal/ ac Use of Allotment — Cost 0%–75% — $0.35 75%–100% — $1.00 100%–150% — $1.25 150%–200% — $2.00 200%–250% — $3.00 Over 250% — $3.80 Cost is per 3,785 L (1,000 gal)	• Reduced demand for pressurized irrigation. • Residential customers used 22%, 19%, and 10% less of their allotments in July, August, and September respectively	(Sowby & South, 2023)

Location	System	Impact	Source
Blanding, Utah	• A single system for drinking water and irrigation • Base rate of $22.00 and a tiered rate according to the proportion of the allotment used • Color-Coded System: Water availability determines rates and restrictions • Annual Forecasting: Engineers assess supply using hydrologic models and recommend conditions to the City Council • Proactive Rationing: Water allotments are based on available supply, ensuring conservation without drastic measures • Water Allotment: Equal for all residents (regardless of property/household size) but adjusts seasonally. Minimum indoor allotment: 250 L (66 gal) per person/day (assumes three-person household)	• 14% reduction in water use (2021-2022) • Equity maintained – all users had sufficient indoor water, even during drought • Sustainable model – Blanding's system promotes conservation while preserving revenue.	(Sowby & South, 2023)
California	• Longer use of non-conservation pricing before switching leads to greater water savings upon transition • Reverting to non-conservation pricing causes a 9.8% rebound in water consumption • Longer use of conservation pricing before switching back reduces the rebound effect	• Reduces water use by 2.9% on average • Behavioral impact: Sustained conservation pricing fosters long-term water-saving habits, even after price changes (crowding-in effect)	(Lee et al., 2024)

After evaluating the various tiered pricing systems and considering Cape May's unique context - marked by seasonal population surges, high commercial water demand, aging full-time population and the long term costs of desalination, the team has composed the following tiered pricing illustrations as a way to describe to or Cape May City how mission-aligned pricing can be designed.

6.6.1. Residential And Commercial Distinction Tiered Pricing

1. In this model, for residential users, an Increasing Tiered Pricing structure is envisioned to be implemented, supplemented by conservation surcharges for high-volume users. This model encourages efficient usage while keeping essential water needs affordable for full-time residents.
2. For commercial users, a uniform rate structure would then be proposed to maintain billing simplicity and predictability. This model supports business with consistent operational requirements and avoids penalizing service-oriented establishments that already operate under near 100% efficiency.

The suggested increasing tiered pricing structure envisioned in this model is integrated with a Water Conservation Tax and a Waterborne Tax, both terms described below. This pricing structure is designed to encourage efficient usage, and fund long-term infrastructure improvements. The definition of the pricing components are as follows:

- **Tariff:** The base volumetric charge for water, covering the costs of water abstraction, treatment, and delivery through Cape May's infrastructure. For domestic users, this rate increases with consumption tiers; for businesses, it remains flat to provide billing predictability.
- **Water Conservation Tax (WCT):** A surcharge imposed as a percentage of the base tariff to reflect the scarcity value of water and promote conservation. For households, it applies only to higher usage tiers. For businesses, it is applied universally to ensure shared responsibility in reducing water demand.
- **Waterborne Tax (WBT):** A flat charge applied per cubic meter of water to account for wastewater management. This fee supports the operation and maintenance of Cape May's sewerage network and the treatment of used water.

Due to the universal application of both the WCT and WBT on businesses, businesses consistently pay higher per-unit cost than most residential users, even under a flat tariff structure.

Table 10: Domestic (Households) Tiered Pricing
Created by Authors, A,B,C are Arbitrary Placeholder Numbers, Concept Source: (Public Utilities Board, Singapore)

DOMESTIC (HOUSEHOLDS):

	Price ($/gallon)	
Monthly Water Usage	**0 – 10,000 gallons**	**>10,000 gallons**
Tariff	**$a**	**$b**
Water Conservation Tax (% of Tariff)	**-**	**$c**
Waterborne Tax	**$d**	**$e**
Total Price	**$a + $d**	**$b + $c + $e**

Domestic users will, for any water usage exceeding the 10,000 gallons marginal threshold foreseen in this model, pay a higher base tariff and a conservation tax that applies only to the volume consumed above this threshold. This structure is designed to promote efficiency in non-essential or discretionary water use while maintaining affordability for basic household needs. A monthly usage limit of 10,000 gallons has been identified as the cutoff point between baseline and excess consumption tiers. An average New Jersey household consumes 3750 gallons per month which suggests that the average New Jersey household consumes significantly less than the US national average of 9000 gallons per month (EPA Watersense, 2010).The first 10,000 gallons of the month is thus treated as a "lifeline block" which is priced affordably to cover everyday residential use. Consumption above 10,000 gallons per month signals either excess or non-essential use, triggering the higher tariff and conservation surcharge designed to promote responsible water behavior.

Setting the threshold at 10,000 gallons provides several advantages:

1. Covers essential household needs for nearly all full-time residents (US EPA, 2025)

2. Avoids penalizing low- and moderate-income households, seniors

3. Ensures that only high-volume, discretionary use such as inefficient appliances is subject to higher tariffs and conservation taxes

4. Aligns with international benchmarks such as Singapore and parts of California, where tier cutoffs are similarly based on basic needs (PUB, nd).

Table 11: Non-Domestic Tiered Pricing
Created by Authors, A,B,C are Arbitrary Placeholder Numbers, Concept Source: (Public Utilities Board, Singapore)

NON-DOMESTIC (BUSINESSES):

	Price ($/gallon)
Tariff	$a
Water Conservation Tax (% of Tariff)	$b
Waterborne Tax	$d
Total Price	$a + $b + $d

In this illustration, non-domestic accounts such as hotels, restaurants would be charged a consistent regardless of consumption tier, but would also be subject to a conservation tax to ensure accountability for theirese higher-volume usagees. For commercial users, the pricing structure applies a constant rate per gallon regardless of total consumption volume.This approach reflects the team's acknowledgement that many commercial establishments, especially those in the hospitality industry and food service sectors, might already be operating at or near optimal efficiency due to high operational costs and rigorous service delivery standards. These businesses are not only central to Cape May's economic identity, but also contribute significantly to local employment and tourism-driven revenue. As such, imposing a tiered pricing structure similar to that proposed for domestic users could disproportionately burden these essential contributors, especially during the high-demand summer months.

However, to ensure that all users contribute to the cost of municipal water stewardship, a WCT would be applied as a percentage of the base tariff. This tax reflects the expectation that commercial entities, with greater access to capital and infrastructure, are better positioned to invest in water-saving technologies, fixtures, and operational practices. By embedding this incentive directly into the pricing structure, the city would also encourage businesses to take proactive steps toward conservation, while keeping their base rate predictable and manageable.

To help manage peak demand during the high-use summer months, the City may consider implementing a seasonal surcharge applied exclusively to domestic users. This charge would apply during the months when discretionary household consumption such as pool use and short-term rental turnover significantly increases. The intent would beis to send a targeted pricing signal that reflects the heightened cost and stress placed on the water system during these months, while preserving year-round affordability for essential use.

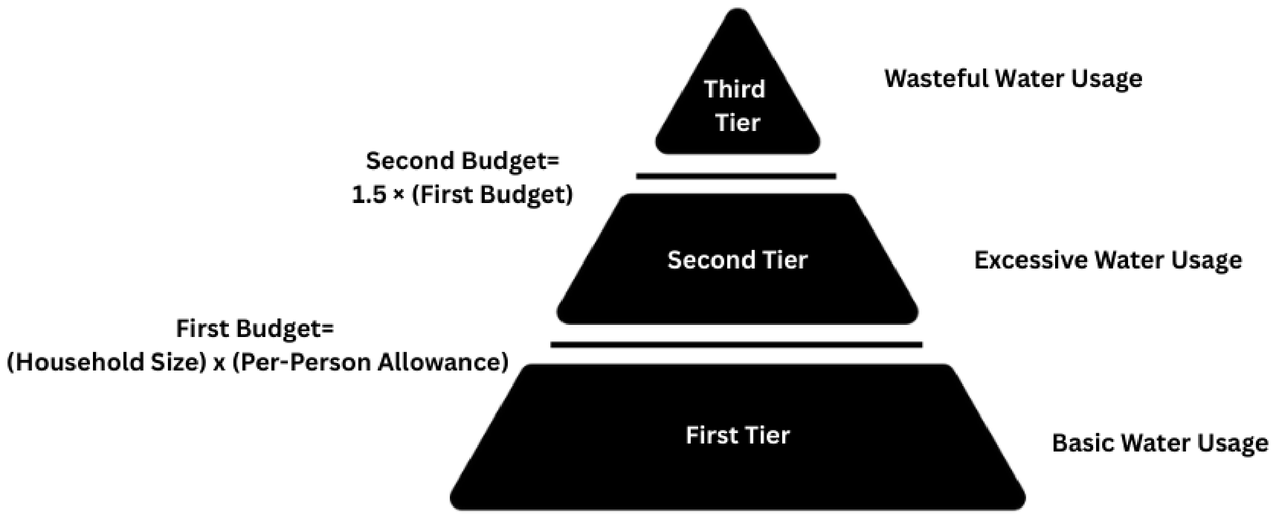
However, it is important to approach this recommendation with nuance. The team recognizes that the introduction of a seasonal surcharge requires careful public communication and policy framing even though it is effective in curbing excessive residential use. Residents, especially part-time homeowners must clearly understand that the surcharge is designed not as a penalty, but as a tool to preserve the city's long-term water resilience. By limiting the surcharge to domestic accounts, the city avoids placing additional financial burden on its commercial sector, which is not only a significant contributor to the local economy but also more likely to operate within efficiency constraints. On the other hand, each residential customer represents a voter and taxpayer within the community. How and whether to pursue this strategy is a debate for Cape May alone.

6.6.2. Residential Household-Specific Tiered Pricing

This tiered pricing system illustration presumes an alternative approach for residential households. This system utilizes household characteristics (e.g. number of people) to establish customized water budgets that determine which tier that household falls into. This methodology is based on the Eastern Municipal Water District (EMWD) of Southern California's pricing structure which reduced water demand by 18 percent (Baerenklau et al., 2014). Cape May City could employ this tiered pricing strategy for residential households to ensure that basic water necessities remain in the lowest pricing tier while wasteful/excessive usage of water is placed in the highest tier.

Base household budgets in this model would be calculated based on a variety of factors such as household size and per-person allowance. The per-person allowance is a preset value that Cape May City would determine (EMWD set a per-person allowance of 60 gallons per day, for example). The budgets on each tier are then determined based on those factors. For example, the budget for the first tier is determined by multiplying household size by per-person allowance. If you set a per-person allowance of 60 gallons per day, the first tier's budget for a four-person household would be 240 gallons per day. In order for that household to remain in the first pricing tier, they would need to remain below 240 gallons per day. The second tier's budget is simply a multiple of the first tier's budget. This creates three different tiers: basic water usage, excessive water usage and wasteful water usage (ordered from lowest to highest usage). Figure 12 below illustrates this system.

Figure 12: Household-Specific Tiered Structure
Created by Authors, Concept Source: (Baerenklau et al., 2014)



First Tier: Basic Water Usage

Any households that remain below the first budget threshold would be in the first tier and pay the lowest rate. Continuing on the previous example of a four person household with a 60 gallons per-person allowance, this household would need to remain below 240 gallons per day to stay in the first tier. Note that the 60 gallons per-person allowance is an example. The per-person allowance should be set to a reasonable amount of water to fulfill basic necessities for Cape May City's context.

This tier is paying the lowest rate. This rate might be similar or lower to the current lowest rate for water in Cape May City, depending upon how the city wants to approximate true cost or how it defines the best way to ensure stakeholder buy-in, for example. Setting this rate even lower could help the public reception of this tiered pricing system as households who remain in the first tier may save money over current billing. Generally speaking, this tier could reward year-round residents who are careful about their water consumption.

Cape May City might also consider adding extra factors to the first budget's calculation. One example could be a peak season factor that lowers these budgets so households are incentivized to be more water conscious in the peak season. Conversely, adding a low-income household factor that raises the budget (i.e. raises the water allowance for this household) would ensure that low-income households are not heavily impacted by this system.

Second Tier: Excessive Water Usage

The second tier represents the rate paid by any households that exceed the first budget but remain below the second budget. In this illustration, the second budget is the first budget multiplied by 1.5. Continuing on the previous example, the second budget would be 360 gallons per day (240 multiplied by 1.5).

This tier is paying the middle rate. This rate should be set to a value higher than the current Cape May City excess rate but not drastically above the first tier's rate. Ideally, this tier is for households that are using water for irrigation but are still decently conscious about their consumption.

Third Tier: Wasteful Water Usage

The third and highest tier represents households that exceed the second budget. This should be composed of households that are wastefully using water (e.g. excessive lawn watering in peak season). The pricing should be significantly higher than the first and second tier.

Overall, this approach to residential tiered pricing gives Cape May City a way of protecting residents who are conscious about their water consumption while penalizing those who are not. Low-income residents who simply use water for basic necessities would in this case not pay a higher rate, they may even be saving money on water with this system. The methodology of this system is also highly customizable. As mentioned, different factors can be introduced such as a peak season factor to lower the budget levels during summer. Ultimately, Cape May City can customize this conceptual framework to meet the needs of its community.

One consideration to make about this model is that it requires comprehensive data on household sizes for each account that is billed. If this information is not readily available, it may take time to obtain. The city should also be careful when determining the per-person allowance. This value needs to be set such that it is sufficient to fulfill daily water needs. The example value from the EMWD is 60 gallons per day, whereas, the EPA states that the average American uses 82 gallons per day (EPA, 2025). We recommend Cape May City to analyze the water consumption patterns of properties without excessive amenities (pools or gardens) to determine a per-person allowance.

As Cape May continues to navigate the challenges of growing water demand and long-term sustainability, the team suggests the city to view pricing not just as a financial tool, but as a policy lever that can shape behavior, drive investment in efficiency, and generate funding for system improvements. Clear communication, public engagement, and adaptive policy design would be essential for successful implementations. Ultimately, leveraging tiered pricing as a policy mechanism to influence behavior is a policy decision that rests with Cape May. It may serve as a flexible mechanism to promote conservation especially if paired with rebate programs and clear usage alerts. The most effective pricing strategy may be the one that reflects not only the technical findings of this report, but also the City's broader vision for equity, resilience, and water stewardship.

Financial Feasibility

In order to guarantee access to reliable potable water for years to come, Cape May City needs to ensure that municipal water infrastructure is operated sustainably. Economic viability is a key element of sustainable operation and minimizes the financial burden on the municipality and taxpayers.

Cape May City has a strong track record of fiscal responsibility. As we will see in the following section, municipal water and sewer infrastructure is operated on a profitable basis today. Major capital expenses have been funded through grants and low-cost, tax-exempt bonds or loans. Responsible financial management has enabled the municipality to accumulate a capital surplus, which provides protection against unexpected future costs and allows for strategic capital investment.

As part of this capstone project, we assessed the financial positioning of the Cape May Water & Sewer Utility to determine recommendations to improve the long-term financial viability of the proposed new desalination plant. For the sake of this exercise, all cost assumptions are based on the operations of the existing plant. Based on guidance from the Chief Financial Officer of Cape May City, we have broadly assumed that 60% of the utility budget is allocated to water services (with the remaining 40% to sewer) and that 80% of the total energy consumption of the utility is directly attributable to the desalination plant.

In the financial section of this report, we will evaluate the recommendations presented in prior sections from an economic perspective. Our goal is to estimate the net financial impact of the major solutions contemplated: (1) launching a rebate program for water-efficient fixtures; (2) installing energy recovery devices at the desalination plant; and (3) developing onsite photovoltaic solar generation at the desalination plant. The hope is that our illustrative financial analysis will help Cape May City decision-makers confidently weigh social, environmental, operational, and financial trade-offs. Ultimately, having a clear view of the financial impact of new initiatives can serve to allow the city to continue to maintain strong fiscal discipline and operate infrastructure in a sustainable manner.

7.1. High-Level Current Financial Overview

Cape May City water and sewer systems are managed by a self-liquidating utility – the Cape May Water & Sewer Utility – which is segregated from the city budget. The utility manages the construction and maintenance of infrastructure for sewage treatment and water distribution, including the reverse-osmosis desalination plant. Both systems have served the public of Cape May since 1910.

The Cape May Water & Sewer Utility is a self-liquidating entity, which means that revenue generated is sufficient to cover all operating expenses, salaries and debt service payments of the utility. The utility maintains two funds — an Operating Fund and a Capital Fund. The Operating Fund collects water and sewer rents and pays salaries, operating expenses, and capital expenses. Any surplus profit generated in a given year is rolled into the Capital Fund to support future budget shortfalls and capital expenditures. The utility budget must be balanced on an annual cash basis using the surplus Operating Fund profit or drawing from the Capital Fund balance. All financial figures presented in this section were taken from the Cape May City's audited regulatory annual financial statements.

The utility generates the majority of revenue by collecting water and sewer rents from residential and commercial customers across Cape May City. The water and sewer rates were last reset around a decade ago and have since only been adjusted for inflation based on increases in the Consumer Price Index (CPI). The total income reported by the utility was relatively stable during the period from 2018-2022, increasing by an average year-over-year growth of 3.8% from $7,440,185 in 2018 to $8,639,329 in 2022. In 2023 (the last year of audited financials), total income declined to $8,012,759 driven by a 5.7% decrease in water and sewer rents collected (Table 12). In addition to collecting water and sewer rents, the utility also reports an "other income" line which includes fees collected for various services and late payments. In recent years, water and sewer rents have typically comprised an average 85% of total income, with the remaining 15% from related fees (Figure 13).

The utility has three major expense categories which are salaries and wages, operating expenses, and capital expenses. Total expenses were relatively stable during the period from 2018-2022 with year-over-year variance typically <1.0% in individual categories (Table 12). Operating expenses include all ongoing costs for the operation and maintenance of the reverse-osmosis desalination plant.

The utility has consistently generated an operating profit in recent years. During the period from 2018 to 2023, the utility reported a cumulative net income of $4,314,717. The Operating Fund balance grew from $967,680 at the beginning of the period to $2,431,249 in 2023 (Table 12). This surplus can be used to cover future budget shortfalls or for reinvestment in infrastructure maintenance and upgrades.

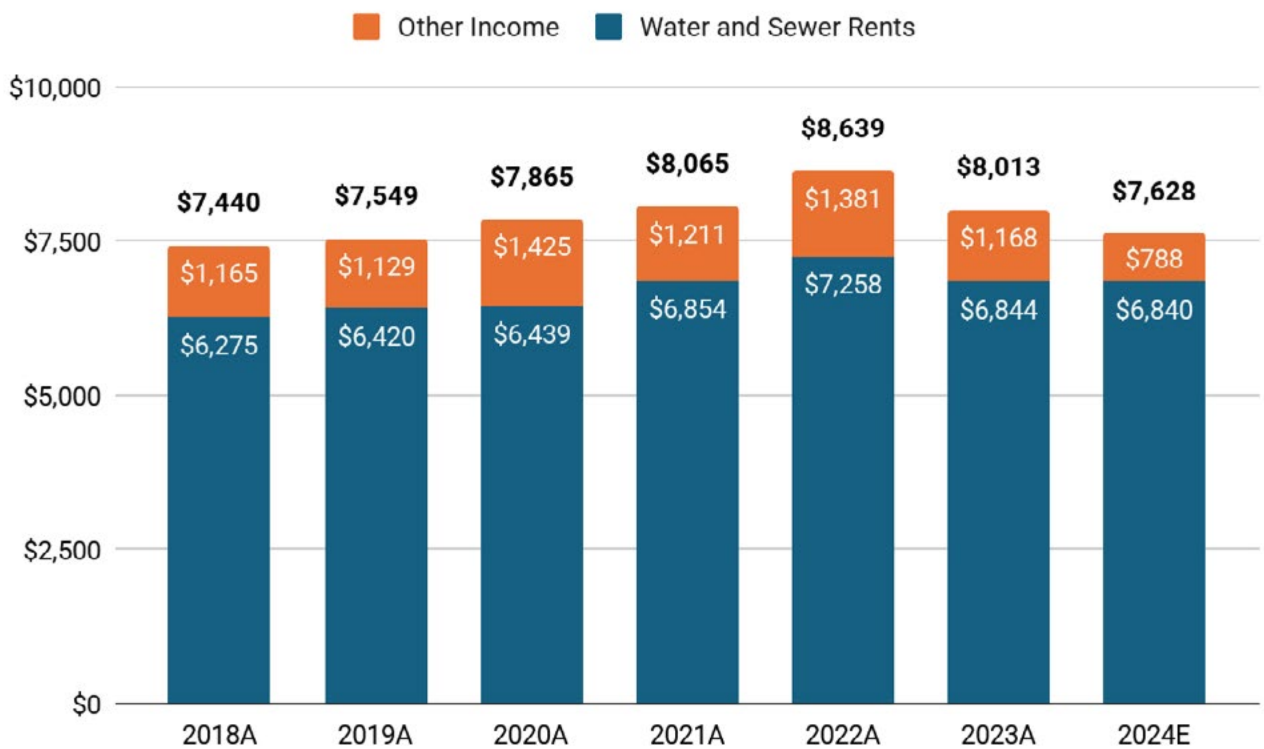
Table 12: Historical Financial Summary For Cape May Water & Sewer Utility (2018A-2024E)
Created by Authors, Data Source: Cape May Audited Financial Statements

HISTORICAL FINANCIAL SUMMARY

($) Regulatory basis as of December 31:	2018A	2019A	2020A	2021A	2022A	2023A	2024E
INCOME							
Water and Sewer Rents	6,275,219	6,419,756	6,439,189	6,853,780	7,258,437	6,844,348	6,840,000
Other Income	1,164,966	1,129,300	1,425,386	1,211,109	1,380,892	1,168,411	787,500
Total Income	**7,440,185**	**7,549,056**	**7,864,575**	**8,064,889**	**8,639,329**	**8,012,759**	**7,627,500**
Rents: YoY growth rate (%)	-	*2.3%*	*0.3%*	*6.4%*	*5.9%*	*(5.7%)*	*(0.1%)*
Income: YoY growth rate (%)	-	*1.5%*	*4.2%*	*2.5%*	*7.1%*	*(7.3%)*	*(4.8%)*
EXPENDITURES							
Salaries and Wages	780,000	827,000	825,250	820,000	880,355	900,000	1,000,000
Operational Expenses	4,475,020	4,431,850	4,418,100	4,703,500	4,730,450	4,750,000	4,700,000
Capital Expenses	1,674,457	1,625,762	1,931,405	1,598,721	1,646,971	1,793,744	1,740,000
Total Expenditures	**6,929,477**	**6,884,612**	**7,174,755**	**7,122,221**	**7,257,776**	**7,443,744**	**7,440,000**
Salaries: YoY growth rate (%)	-	*6.0%*	*(0.2%)*	*(0.6%)*	*7.4%*	*2.2%*	*11.1%*
Op Ex: YoY growth rate (%)	-	*(1.0%)*	*(0.3%)*	*6.5%*	*0.6%*	*0.4%*	*(1.1%)*
NET INCOME							
Total Excess in Revenue	510,708	664,444	689,820	942,668	1,381,553	569,015	187,500
Adjustments	20,872	67,216	0	0	0	0	0
Total Net Income	**531,580**	**731,660**	**689,820**	**942,668**	**1,381,553**	**569,015**	**187,500**
Net Income: YoY growth rate (%)	-	*37.6%*	*(5.7%)*	*36.7%*	*46.6%*	*(58.8%)*	*(67.0%)*
OPERATING FUND BALANCE							
Balance: Beginning of Period (Jan. 1)	967,660	766,925	898,586	913,406	1,338,074	2,185,322	
(-) Utilization as Anticipated Revenue	(732,314)	(600,000)	(675,000)	(518,000)	(534,305)	(323,088)	
(+) Excess in Operations	531,580	731,660	689,820	942,668	1,381,553	569,015	
Balance: End of Period (Dec. 31)	**766,925**	**898,586**	**913,406**	**1,338,074**	**2,185,322**	**2,431,249**	
Balance: YoY growth rate (%)	-	*17.2%*	*1.6%*	*46.5%*	*63.3%*	*11.3%*	

Figure note: *Cape May City reports audited annual financial statements on a regulatory basis. These financial statements are prepared in accordance with the basis of accounting prescribed by the Division of Local Government Services, Department of Community Affairs, State of New Jersey. Statements are audited by an independent firm based on the standards applicable to financial audits contained in Government Auditing Standards, issued by the Comptroller General of the United States.*

Figure 13: Historical Revenue Breakout For Cape May Water & Sewer Utility (2018A-2024E)
Created by Authors, Data Source: Cape May Audited Financial Statem

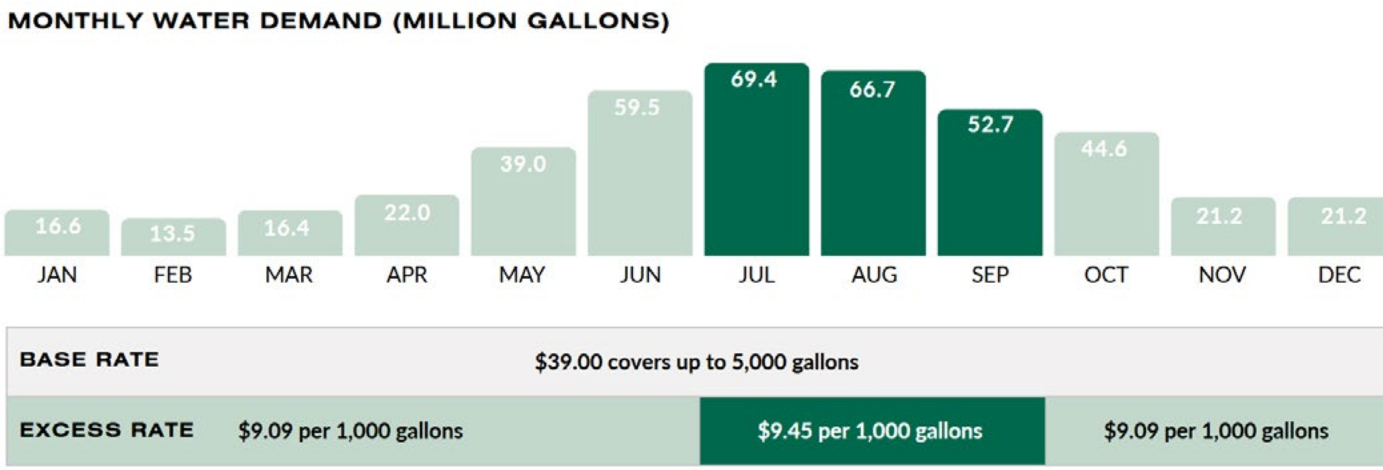


7.2. Revenue Levers

7.2.1. Current Revenue Overview

As discussed above, the Cape May Water & Sewer Utility generates the majority of revenue from collecting water and sewer rents from residential and commercial customers. As discussed previously in this report, Cape May City experiences a sharp spike in monthly water demand during the summer periods due to an influx of seasonal visitors. In 2024, water demand during the 3rd quarter was 1.6-4.0x higher than the other periods. 3rd quarter demand was ~189 million gallons, which was 4.0x higher than the 1st quarter (~47 million gallons), 1.6x higher than the 2nd quarter (~121 million gallons), and 2.2x higher than the 4th quarter (~87 million gallons) (Figure 14).

Figure 14: Cape May Monthly Water Demand And Rate Schedule (2024)
Created by Authors, Data Source: Cape May Water Production Data



Cape May City's current rate schedule is shown below (Figure 15). The existing rate design has basic tiering adjustments for individual meter consumption and seasonality. All customers pay a standard rate of $39.00 per quarter for up to 5,000 gallons of water consumed during that period. If the 5,000 gallon threshold is exceeded, the customer would pay an excess rate of $9.09 per additional 1,000 gallons (compared to the base rate of $7.80 per 1,000 gallons in the initial tier).

Additionally, the excess consumption rate is increased to $9.45 per 1,000 gallons in the third quarter (months of July, August and September). The water base and excess rates were last increased a decade ago and have only been adjusted for inflation. By charging higher rates for excess consumption and usage during peak demand periods, the utility is providing a financial disincentive to customers for consuming excess water.

Figure 15: Current Rate Schedule For Cape May Water & Sewer Utility (As Of April 2025)
Source: Cape May Water & Sewer Utility website

SUMMARY OF RATES AND TERMS

5,000 Minimum gallons plus (additional 1,000 gallon excess rate on anything over 5,000 gallons)

	Water	Sewer	Total
Minimum charge includes: 5,000 gallons	$39.00	$71.40	$110.40
Excess Rate: over 5,000 gallons - **First, Second & Fourth Quarters**	$9.09	$18.10	$27.19
Excess Rate: over 5,000 gallons - **Third Quarter**	$9.45	$18.10	$27.55

Basis of rates:

A minimum water rate of $39.00 is assessed for up to 5,000 gallons of water used. The minimum sewer rate for that same 5,000 gallons of water used will be $71.40.

For all water used over 5,000 gallons there will be an excess rate of $9.09/1,000 gallons in the 1st, 2nd & 4th quarters and $9.45/1,000 gallons in the 3rd quarter.

7.2.2. Appliance Rebate Program

As discussed in Section 6.5.1. (Incentivizing Water-Efficient Technology), rebates can be an effective tool to incentivize commercial and residential customers to install more water-efficient appliances. If a rebate program was deployed at scale, it could reduce water consumption across the municipality without requiring significant changes in consumer behavior. We believe that rebates are a cost effective intervention when measured on a per unit basis — i.e. cost per water saved ($/gallon).

This intervention may result in a slight decrease in utility revenue, given consumers are using — and therefore paying for — less water. However, a reduction in water consumption can help to prolong the useful life of the desalination plant, as equipment longevity is based on production volumes, and extend the lifetime of the aquifers. The Mayor's Office has expressed that extending the useful life of the desalination plant and aquifers are key priorities for the city. We believe that a rebate program is a cost effective, measurable, permanent and impactful way to achieve these goals. The program also has positive co-benefits, such as supporting the tourism industry which is a bedrock of the local economy.

To illustrate the cost and impact of implementing a rebate program in Cape May City, we selected two representative water-efficient appliances and calculated their potential lifetime reduction in water usage. We considered the financial impact at the unit and customer levels to help Cape May City articulate the benefits of the rebate program to prospective participants.

Finally, we calculated a representative municipality-wide impact by calculating cost and water reduction if the top ten hotels by water consumption participated in the rebate program. We'll conclude this section with a summary of the potential impact of the rebate program on lifetime water savings and the estimated cost to Cape May City.

Unit-Level Analysis: Water Efficient Showerheads and Toilets

To begin, we modeled water-efficient showerhead and toilet retrofits from a cost and water reduction perspective. We estimated upfront retail price, daily appliance usage and water savings using guidance from the U.S. EPA WaterSense program and retailers (Showerheads | US EPA, n.d.) (Residential Toilets | US EPA, 2025) (Home Depot, n.d.). The cost of water ($/gallon) was calculated using the Cape May Water & Sewer Utility rate schedule (Official Website for the City of Cape May NJ - Summary of Rates & Terms, n.d.).

The current base rate for water consumption is $39.00 for the initial 5,000 gallons per meter or roughly $0.008/gallon. Finally, we estimated the expected useful life based on generic guidance from leading plumbers (Benjamin Franklin Plumbing, n.d.) (Plumbing Lab, 2025). All base assumptions are shown in Table 13 (showerheads) and Table 14 (toilets).

Table 13: Base Assumptions For Water-Efficient Showerhead
Created by Authors; Sources: U.S. EPA, Home Depot, Cape May Water & Sewer Utility

Base Assumptions for Water-Efficient Showerheads	
Upfront cost per fixture ($ per fixture)	$30
Water saved by efficient device (gallons per minute)	0.50
Cost of water ($ per gallon)	$0.008
Average shower length (minutes)	8
Uses per day (#)	2
Useful life of device (years)	10

Table 14: Base Assumptions For Water-Efficient Toilet
Created by Authors; Sources: U.S. EPA, Home Depot, Cape May Water & Sewer Utility

Base Assumptions for Water-Efficient Toilets	
Upfront cost per fixture ($ per fixture)	$200
Water saved by efficient device (gallons per use)	0.32
Cost of water ($ per gallon)	$0.008
Uses per day (#)	5
Useful life of device (years)	35

Next, we modeled a range of rebates for each fixture to assess the impact on customer payback period, lifetime cost savings, and cost per water reduction to Cape May City. As discussed in Section 6.5.1, we have assumed that rebates would be paid as a flat reimbursement amount, as opposed to a percentage of customer spending. This approach would help Cape May City limit excess spending and ensure all participants receive equitable proceeds from the program regardless of their size. Alongside a review of comparable rebate programs, this analysis is meant to help Cape May City determine the appropriate rebate level to incentivize participation while minimizing cost to the municipality.

Calculation methodology for impact metrics:

Annual cost savings ($/y) = annual water savings (g/y) x cost of water ($/g)

Lifetime cost savings ($) = annual cost savings ($/y) x useful life of fixture (y) - upfront cost ($)

Customer payback period (y) = (upfront fixture cost ($) - rebate amount ($)) / annual cost savings ($/y)

Annual water savings (g/y) = water savings per usage (g/#) x annual usage (#/y)

Lifetime water savings (g) = annual water savings (g/y) x useful life of fixture(y)

Cost to Cape May per water saved ($/g) = rebate amount ($) / lifetime water savings (g)

For water-efficient showerheads, we evaluated a range of rebates from $0 to $30 which represent 0% to 100% of the estimated retail cost of the fixture. We reviewed comparable rebate programs using the U.S. EPA WaterSense website (see Section 6.5.1) and found that rebates typically ranged from $10-20 per fixture.

Table 15 shows an illustrative rebate analysis for single water-efficient showerhead using the base assumptions (Table 13) and rebate range described above.

Illustrative Rebate Analysis For A Single Water-Efficient Showerhead

Table 15: Illustrative Rebate Analysis For Single Water-Efficient Showerhead
Created by Authors

Rebate		Customer Perspective		Cape May Perspective	
($)	(% of cost)	Payback period (yrs)	Lifetime cost savings ($)	Lifetime water savings (g)	Cost per water saved ($/g)
$0	0%	1.3	$198	29,200	$0.0000
$5	17%	1.1	$203	29,200	$0.0002
$10	33%	0.9	$208	29,200	$0.0003
$15	50%	0.7	$213	29,200	$0.0005
$20	67%	0.4	$218	29,200	$0.0007
$25	83%	0.2	$223	29,200	$0.0009
$30	100%	0.0	$228	29,200	$0.0010

Based on this preliminary analysis, we believe there is a clear incentive for customers to install water-efficient showerheads. For the midpoint rebate range ($10-20), customer payback periods range from 0.4-0.9 years which is well within the estimated useful life of 10 years. At a $15 rebate per fixture, lifetime cost savings from the showerhead would be $213 which is a ~14x return on their upfront $15 investment.

From Cape May City's perspective, a single water-efficient showerhead could result in lifetime water savings of 29,200 gallons. At a $15 rebate per fixture, the city would pay $0.0005 per gallon of water saved. We believe that a rebate for water-efficient showerheads would be an incredibly cost-effective means of incentivizing water conservation.

For water-efficient toilets, we evaluated a range of rebates from $80 to $200 which represent 40% to 100% of the estimated retail cost of the fixture. We reviewed comparable rebate programs using the U.S. EPA WaterSense website (see Section 6.5.1) and found that the average rebate was typically $137.50 per fixture. Table 16 shows an illustrative rebate analysis for single water-efficient toilets using the base assumptions (Table 14) and rebate range described above.

Illustrative Rebate Analysis For A Single Water-Efficient Toilet

Table 16: Illustrative Rebate Analysis For Single Water-Efficient Toilet
Created by Authors

Rebate		Customer Perspective		Cape May Perspective	
($)	(% of cost)	Payback period (yrs)	Lifetime cost savings ($)	Lifetime water savings (g)	Cost per water saved ($/g)
$80	40%	22.0	$39	20,440	$0.0039
$100	50%	22.0	$59	20,440	$0.0049
$120	60%	17.6	$79	20,440	$0.0059
$140	70%	13.2	$99	20,440	$0.0068
$160	80%	8.8	$119	20,440	$0.0078
$180	90%	4.4	$139	20,440	$0.0088
$200	100%	0.0	$159	20,440	$0.0098

Based on this preliminary analysis, we believe that customers would require a relatively higher rebate to adopt water-efficient toilets versus showerheads. For the rebate range based on comparable programs ($120-160), customer payback periods range from 9-18 years which is well within the estimated useful life of 35 years. At a $140 rebate per fixture, lifetime cost savings from the toilet would be $99 which is a ~2.5x return on their upfront $40 investment. From Cape May City's perspective, a single water-efficient toilet could result in lifetime water savings of 20,440 gallons. At a $140 rebate per device, the city would pay $0.0068 per gallon of water saved. While marginally less cost effective than water-efficient showerheads, this rebate would still allow Cape May City to significantly reduce lifetime water consumption at a reasonably low cost to the municipality.

Customer-Level Analysis: Chalfonte Hotel

Next, we evaluated the financial impact of water-efficient retrofits at the customer level using the Historic Chalfonte Hotel as a sample commercial water user. The Chalfonte Hotel has 65 individual guestrooms on the property (The Chalfonte Hotel, n.d.). We assumed that each guestroom has 1 showerhead and 1 toilet and that there are 5 additional toilets throughout the property in the lobby, kitchen, and staff rooms. We applied a municipal rebate of $15 per showerhead and $140 per toilet which represent 50% and 70% of retail price, respectively. The remainder of the assumptions for this analysis, such as cost savings and water reduction, were taken from our unit-level calculations in the previous section. These base assumptions are summarized below in Table 17.

Table 17: Base Assumptions For Chalfonte Hotel Retrofit Analysis
Created by Authors; Source: The Chalfonte Hotel website

Base Assumptions for Chalfonte Hotel Retrofit Analysis	
Showerheads (#)	65
Toilets (#)	70
Showerhead rebate ($ per fixture)	$15
Toilet rebate ($ per fixture)	$140
Note: Retail unit price, water cost, water reduction, and cost savings same as per-unit above	

For our customer-level analysis, we calculated the total upfront cost and lifetime cost savings to estimate an overall payback period and return on investment for the Chalfonte Hotel if they retrofit all of their showerheads and toilets with water-efficient models.

The output of this analysis is shown below in Table 18. All calculations were done using the base assumptions listed above in Table 17 and the metric formulas written out below.

Calculation methodology for impact metrics:
Upfront cost ($) = (retail price ($) - rebate amount ($)) x number of fixtures (x)
5-year cost savings ($) = annual cost savings ($/y) x 5 years - upfront cost ($)
Lifetime cost savings ($) = annual cost savings ($/y) x useful life of fixtures (y) - upfront cost ($)
Return on investment (x) = (lifetime cost savings ($) - upfront cost ($)) / upfront cost ($)
Customer payback period (y) = (upfront cost ($) / annual cost savings ($/y)

Illustrative Return Analysis For Single Hotel

Table 18: Illustrative Water-Efficient Retrofit Analysis For Chalfonte Hotel
Created by Authors

Hotel Scale		Rebate		Total Costs to Hotel ($)			Return Analysis	
	(#)	($)	(% of cost)	Upfront cost	5-year cost savings	Lifetime cost savings	Return on investment (x)	Payback period (yrs)
Showerhead	65	$15	50%	$975	$6,427	$13,829	15.2	0.7
Toilet	70	$140	70%	$4,200	($2,606)	$6,960	2.7	13.2
Total				**$5,175**	**$3,822**	**$20,790**	**5.0**	

Based on this preliminary analysis, we believe there is a clear incentive for large hotels to participate in a municipal rebate program for water-efficient retrofits. If the Chalfonte Hotel were to retrofit all of their existing showerheads and toilets, we estimate that they could generate lifetime cost savings of $20,790 for a roughly 5.0x return on their post-rebate upfront investment of $5,175. As Cape May engages with large hotels on the proposed rebate program, we would recommend that the city emphasizes long-term cost savings as a primary benefit to hotels.

Based on account-level water consumption provided by Cape May City, the Chalfonte Hotel used 1,510,768 gallons in 2024. If the hotel were to pursue the retrofits described above, we calculate that annual water savings would be meaningful at ~230,000 gallons. This represents a roughly 15% reduction in the Chalfonte Hotel's annual water consumption due to the replacement of showerheads and toilets with more water-efficient models.

Sample Municipal-Level Analysis: Aggregate Impact And Cost To Cape May City

Lastly, we estimated the potential total impact of the proposed rebate program by calculating the lifetime water savings if the top ten hotels by 2024 water consumption participated. To start, we replicated the customer-level analysis done for the Chalfonte Hotel above for each of the target hotels. Based on information available on the hotel public websites, we calculated that the total number of showerheads and toilets for the target population was 910 and 960, respectively. All base assumptions for the rebate program are included in Table 19; hotel specific assumptions are included in Table 20.

Table 19: Base Assumptions For Rebate Program Aggregate Analysis
Created by Authors

Base Assumptions for rebate program aggregate analysis	
Showerheads (#)	910
Toilets (#)	960
Showerhead rebate ($ per fixture)	$15
Toilet rebate ($ per fixture)	$140
Program administration cost ($)	$10,000
Note: Retail unit price, water cost, water reduction, and cost savings same as per-unit above	

Table 20: Summary Of Top 10 Hotels By 2024 Water Usage
Created by Authors; Source: Hotel websites and travel agencies

Summary of top 10 hotels by 2024 water usage (gallons)				
Hotel	**Annual water usage, 2024 (g)**	**Guestrooms (#)**	**Showerheads (#)**	**Toilets**
Congress Hall	10,248,000	106	106	111
Grand Hotel	8,821,000	165	165	170
The Beach Shack	4,640,630	77	77	82
La Mer Beachfront Resort	3,937,530	162	162	167
Marquis de Lafayette	3,620,432	82	82	87
Sandpiper Beach Club	2,752,000	51	51	56
Montreal Beach Resort	2,594,819	70	70	75
Ocean Club Hotel	2,408,000	90	90	95
The Inn of Cape May	1,914,554	51	51	56
ICONA Cape May	1,773,040	56	56	61
Total	**42,710,005**	**910**	**910**	**960**

For our municipal-level analysis, we calculated the total cost to Cape May City and lifetime water savings if the top ten hotels by water consumption participate in the rebate program.

The output of this analysis is shown below in Table 21. All calculations were done using the base assumptions listed above in Table 19 and the metric formulas written out below.

Calculation methodology for impact metrics:

Rebate payments ($) = rebate amount per fixture ($) x number of fixtures (x)

Total cost ($) = rebate payments ($) + program administration costs ($)

Lifetime water savings (g) = annual water savings per fixture (g/x/y) x number of fixtures (x) x useful life of fixtures (y)

Cost per water saved ($/g) = total cost ($) / lifetime water savings (g)

Illustrative Return Analysis For Full Program With Target 10 Hotels Participating

Table 21: Illustrative Impact Of Proposed Rebate Program To Cape May City
Created by Authors

Program Scale		Rebate		Total Costs to Cape May ($)			Impact Analysis	
	(#)	($)	(% of cost)	Program administration	Rebate payments	Total costs	Lifetime water savings (g)	Cost per water saved ($/g)
Showerhead	910	$15	50%	$5,000	$13,650	$18,650	26,572,000	$0.001
Toilet	960	$140	70%	$5,000	$134,400	$139,400	19,622,400	$0.007
Total				**$10,000**	**$148,050**	**$158,050**	**46,194,400**	**$0.003**

If the top ten hotels by water consumption participated in the proposed rebate program, the lifetime water savings resulting from the program could be over 45,000,000 gallons. We estimated that the upfront cost to Cape May City would be around $160,000, of which roughly $150,000 would be distributed to the hotel participants as direct rebates and the remaining $10,000 would cover program administration overhead. At a cost of $0.003 per gallon of water saved, the rebate program would be a cost effective intervention which could drive measurable water conservation with minimal behavioral modifications or impact to user experience.

Lastly, we evaluated the potential impact of the rebate program on each of the target hotels. We estimated the annual water savings in gallons by multiplying the hotel's total number of showerheads and toilets by the respective annual water savings calculated in the unit-level section above. We then expressed the water savings as a percentage of the hotel's water consumption in 2024. Finally, we calculated the lifetime cost savings to the hotel after accounting for upfront costs. The output of this analysis is shown below in Table 22. All calculations were done using the base assumptions listed above in Table 20 and the metric formulas written out below.

Calculation methodology for impact metrics:

Annual water savings (g/y) = annual water savings per fixture (g/x/y) x number of fixtures (x)

Reduction (%) = annual water usage, 2024 (g/y) / annual water savings (g/y)

Lifetime savings cost ($) = total cost savings ($) - (total upfront cost ($) - rebates ($))

Table 22: Illustrative Impact Of Rebate Program On Target Hotels
Created by Authors: Source: Cape May Quarterly Water Usage by Account Report

Illustrative impact of rebate program on target hotels				
Hotel	**Annual water usage, 2024 (g)**	**Annual water savings (g)**	**Reduction (%)**	**Lifetime cost savings ($)**
Congress Hall	10,248,000	374,344	3.7%	$33,590
Grand Hotel	8,821,000	581,080	6.6%	$52,009
The Beach Shack	4,640,630	272,728	5.9%	$24,536
La Mer Beachfront Resort	3,937,530	570,568	14.5%	$51,072
Marquis de Lafayette	3,620,432	290,248	8.0%	$26,097
Sandpiper Beach Club	2,752,000	181,624	6.6%	$16,419
Montreal Beach Resort	2,594,819	248,200	9.6%	$22,351
Ocean Club Hotel	2,408,000	318,280	13.2%	$28,594
The Inn of Cape May	1,914,554	181,624	9.5%	$16,419
ICONA Cape May	1,773,040	199,144	11.2%	$17,980
Total	**42,710,005**	**3,217,840**	**7.5%**	**$289,066**

Based on this analysis, we believe that the rebate program could generate meaningful water consumption reduction and lifetime cost savings for all of the target hotels. We estimated that the retrofits of water-efficient fixtures could reduce the total annual water consumption of the hotels by 4-15% with an average of 7.5%. The wide variance is driven mainly by the divergence in water consumption habits amongst the hotels. Hotels with water-based amenities (i.e. pools), on-site restaurants, or suite-style rooms (which typically have kitchenettes with sinks and dishwashers) would consume relatively less of their water on simple fixtures such as showerheads and toilets. These hotels would therefore see smaller estimated reductions. We also estimated that each hotel would recognize lifetime cost savings of ~$15,000-$50,000 based on the number of guestrooms, with total lifetime savings across all hotels of ~$289,000 (which far surpasses Cape May City's expected investment of ~$158,000). In general, we believe that the estimated water and cost savings are meaningful enough to justify engagement with the hotels on their participation.

Conclusion: Water-Efficient Rebate Program Proposal

In summary, we propose that Cape May City launch a rebate program for water-efficient retrofits. To start, we recommend that the program offer rebates for showerheads and toilets - two of the most water-intensive building fixtures. Based on comparable rebate programs and per-fixture payback analysis, we suggest offering a rebate of $10-20 per showerhead and $120-160 per toilet. In order to test program reception and minimize administrative burden, we suggest that Cape May City initially offer the program to large commercial hotels. If the top 10 hotels by water consumption participate in the program, it could generate lifetime water savings of more than 45,000,000 gallons. If the program attracts more participants, the scale of water conversation could be even more meaningful.

We believe that setting the rebates at the appropriate levels would make the rebate program economically attractive to both Cape May City and the participants. We calculate that the cost to Cape May City per gallon of water saved could be around $0.003 at scale. We estimated that showerheads would have a payback period of less than 1 year with a 10 year useful life and toilets would have a payback period of 9-17 years with a 35 year useful life. Given the lifetime cost savings on their water bill would exceed the upfront investment, hotels could realize $15,000 to $50,000 in excess savings over the useful life of the fixtures and reduce up to 15% of total annual water consumption.

From this perspective, the program would not only meaningfully reduce water consumption but also support participant hotels and bolster the local tourism industry.

The proposed rebate program may result in a slight decrease in utility revenue, given consumers are using — and therefore paying for — less water. However, a reduction in water consumption could help to prolong the useful life of the desalination plant, as equipment longevity is based on production volumes, and extend the lifetime of the aquifers. The Mayor's Office of Cape May City has expressed that extending the useful life of the desalination plant and aquifers are key priorities.

7.3. Expense Levers

7.3.1. Current Expense Overview

As discussed above, the Cape May Water & Sewer Utility has three major expense categories — salaries and wages, operating expenses, and capital expenses. For the sake of financial review and with guidance from the Mayor's Office, we have assumed that all ongoing costs for the operation and maintenance of the reverse-osmosis desalination plant are included in operating expenses. Based on guidance from the Chief Financial Officer of Cape May City, we have assumed that 80% of the total energy consumption of municipal buildings is directly attributable to the desalination plant.

We conducted a literature review of publicly available financial information on existing desalination plants. In general, operating costs account for two-thirds of lifetime water production costs with the remaining one-third based on upfront capital costs. Within the operating costs, energy consumption is typically the largest expense.

Studies suggest that "energy accounts for 50% of the operation cost when membranes, pumps and energy recovery devices with standard efficiency are used." (Busch & Mickols, 2004) Given energy is a major expense for desalination, we focused our operational financial analysis on ways to reduce energy costs.

Cape May City purchases electricity from Atlantic City Electric (An Exelon Company) to power all municipal buildings and operations, including the desalination plant. Based on historical 2024 utility bills provided by the Mayor's Office, total energy consumption was 1,296,315 kWh and the total cost of electricity for the city was $218,863 during that period. As mentioned above, we further assumed that 80% of the total energy consumption is directly attributable to the desalination plant. Using this assumption, we estimated that the desalination plant consumed 1,037,052 kWh in 2024 for a total cost of $175,090 (Table 23).

Table 23: Summary Of Energy Consumption And Utility Charges For Cape May City (2024)
Created by Authors; Source: Cape May Historical Utility Bills

Month	Consumption (kWh)	Unavoidable Cost ($)	Avoidable Cost ($)	Total Cost ($)
Jan	80,477	$5,909	$8,376	$14,285
Feb	69,643	$5,555	$7,387	$12,943
Mar	68,742	$5,778	$7,292	$13,070
Apr	67,993	$5,592	$7,187	$12,779
May	85,949	$5,405	$9,025	$14,430
Jun	121,412	$6,246	$13,726	$19,971
Jul	154,831	$6,379	$19,662	$26,040
Aug	168,710	$4,192	$22,311	$26,503
Sep	154,187	$3,863	$20,399	$24,263
Oct	132,273	$3,626	$17,570	$21,196
Nov	114,037	$3,827	$15,256	$19,083
Dec	78,061	$3,775	$10,525	$14,300
Total	**1,296,315**	**$60,148**	**$158,715**	**$218,863**
Plant	**1,037,052**	**$48,118**	**$126,972**	**$175,090**

From a pricing perspective, we calculated Cape May City's total consumption rate in 2024 to be $0.17/kWh by taking the total cost of electricity ($218,863) and dividing by the total consumption in (1,296,315 kWh). For further clarity, we divided the energy rate into two components: a fixed rate and a variable rate. We separated all of the charges from Cape May City's utility bills into two categories — avoidable costs and unavoidable costs, shown in Figure 16.

Broadly speaking, avoidable costs included any charge that is assessed on a consumption basis ($/kWh) and unavoidable costs included charges assessed on a capacity basis (kW). The avoidable rate ($/kWh) charges are boxed in orange in the below graphic. We then calculated the city's variable rate for electricity by analyzing all of the avoidable costs in the utility bills and dividing the sum by the total consumption. Based on this methodology, the variable rate in 2024 was $0.12/kWh.

Figure 16: Avoidable ($/kwh) Costs On A Utility Bill
Source: Client Provided Utility Bill

Delivery Charges: These charges reflect the cost of bringing electricity to you.
Current charges for 30 days, **summer rates in effect.**
Capacity/Transmission Peak Load Contribution 270.61 / 300.21

Type of charge	How we calculate this charge	Amount($)
Customer Charge		193.22
Distribution Charge	266.92 kW X $13.7500000 per kW	3,670.15
Non-Utility Generation Charge	154187 kWh X $0.0036720 per kWh	566.17
Societal Benefits Charge	154187 kWh X $0.0105550 per kWh	1,627.45
RGGI Energy Efficiency	154187 kWh X $0.0042290 per kWh	652.05
Conservation Incent Prog	266.92 kW X $0.1899820- per kW	50.71–
Zero Emission Certif (ZEC) Charge	154187 kWh X $0.0042650 per kWh	657.61

For the sake of this report, we have assumed that any initiatives which would improve energy efficiency or supply behind-the-meter power would only reduce the total energy consumed (kWh) by the desalination plant. As a result of this assumption, any financial impact from our proposals would only affect the consumption charges — aka the avoidable costs and the variable rate paid by Cape May City. For the remainder of this section, we will assume that run-rate annual energy consumption for the desalination plant is 1,037,052 kWh and avoidable costs are $126,972 per annum (Table 23).

For this project, we evaluated potential actions which Cape May City can take to reduce expenses and improve the long-term financial sustainability for the desalination plant. We identified energy costs as the most feasible and highest return expense line to target for this exercise. We determined this given (1) literature indications that energy costs are typically the most significant portion of plant operating costs (Busch & Mickols, 2004); (2) readily available historical data in the form of municipal utility bills; and (3) feasibility of energy efficiency and behind-the-meter energy generation alternatives.

We used a similar deliberation framework to determine not evaluate other expenses, based on the magnitude of impact, data, and feasibility of potential alternative solutions. For example, upfront capital costs are largely static and based on market prices for engineering services and equipment. Similarly, salaries and wages are paid at the utility level and the Mayor's Office indicated there was no need to review personnel.

In the following subsections, we will present our findings on several alternatives which could enable Cape May City to either improve energy efficiency or generate on-site energy - both of which would reduce the operating costs of the desalination plant in the long run.

7.3.2. Energy Recovery Devices

As discussed in Section 5.2.2, Energy Recovery Technologies, the implementation of energy recovery devices can achieve a 10–30% reduction in energy consumption for brackish water reverse-osmosis desalination plants. The range of efficiency depends upon the scale of the system, salinity of the feedwater, and operational conditions (Energy Recovery Inc., 2024; Alsarayreh et al., 2020). This reduction in energy consumption would lower monthly utility bills and result in significant operational cost savings for the plant, given that high-pressure and booster pumps typically account for 55–70% of a BWRO facility's total electricity use (Ghaffour et al., 2013).

Our analysis is intended to evaluate the proposed installation of energy recovery devices on the new desalination plant under development. For our calculations, we used historical energy consumption from the existing plant given available data. We expect the modeled payback periods to be directionally accurate as long as energy usage levels are similar across the new and existing plants. To assess the potential cost savings from installing energy recovery devices, we conducted a payback analysis where we compared ongoing cost savings to the initial upfront cost of installing the devices.

To begin, we estimated the upfront expected cost of installing energy recovery devices. Upfront cost ($) was calculated as the number of devices required (#) multiplied by the cost per device ($).

Based on the maximum capacity of the desalination plant, we determined that the plant would need three (3) energy recovery devices. We decided to use PX-Q150 as a reference for our analysis because it matches the new plant's design, and is widely used in the field today. According to an Energy Recovery Inc. sales representative, the devices each have a retail cost of $40,000, and require a VFD and booster pump for its operations, which makes the installed cost approximately $65,000 per unit (Littrell et al., 2022). Based on these assumptions, the total upfront costs of the energy recovery devices were estimated to be $195,000. For simplicity, we assumed that there are no ongoing costs associated with maintaining the devices given we expect these costs to be de minimis relative to the overall existing maintenance costs of the plant.

Next, we estimated the annual cost savings of the devices. Cost savings ($) were calculated as the reduction in energy consumed (kwh) multiplied by the cost of electricity ($/kwh).

As described in Section 5.2.2, a review of relevant case studies suggests that energy recovery devices can achieve a 10–30% reduction in the energy required to pump water for brackish water reverse-osmosis desalination plants (Energy Recovery Inc., 2024). The energy required to pump water is significant and can be 55-70% of the total energy needs of the plant (Ghaffour et al., 2013). As shown in the previous section, estimated annual energy consumption for the desalination plant was 1,037,052 kWh in 2024. For the sake of this analysis, we assumed that the total annual energy needs of the new desalination plant are consistent with the 2024 baseline consumption of the existing plant in all future periods. The total reduction in energy consumption (kwh) from installing energy recovery devices is therefore calculated as the cumulative energy reduction from the devices (%) multiplied by the proportion of total plant energy usage that powers water pumps (%) multiplied by the 2024 baseline annual energy consumption for the plant.

The final variable was the cost of electricity in future periods. As discussed in the previous section, we calculated an avoidable energy cost of $0.12/kWh for the 2024 baseline year. This estimate includes all utility bill charges which are calculated on a consumption basis (i.e. per kWh) and would therefore be impacted by a reduction in total energy consumption (as described further in Figure 16). Given electricity prices are expected to modestly rise over the coming years, we modeled a 2.0% annual increase in the cost of energy from the 2024 baseline.

Table 24: Energy Recovery Device Payback Assumptions
Created by Authors

Energy recovery device payback assumptions	
Cost data	
Devices (#)	Three (3)
Upfront cost per device ($), all-in	$65,000
Total upfront cost, one-time ($)	$195,000
Total operating cost, annual ($)	$0
Energy data	
Total energy consumption, 2024 baseline (kWh)	1,037,052
Energy attributable to water pumps / total plant energy usage (%)	55-70%
Reduction in energy requirements for water pumps from ERDs (%)	10-30%
Avoidable energy cost, 2024 baseline ($/kWh)	$0.12
Inflation in retail electricity prices, annualized (%)	2.0%

We calculated the payback period (years) as the total upfront cost ($) divided by the annual expected cost savings ($/y) using the assumptions in Table 24. For our analysis, we sensitized two variables as discussed above — the percentage by which the energy recovery devices reduce the energy requirements for water pumps and the percentage of total plant energy which is attributable to water pumps. Actual device performance has been shown to range for brackish water desalination, so we ran the payback analysis assuming a 10-30% reduction from the devices in 5% increments (Energy Recovery Inc., 2024).

Based on the energy data available from Cape May City, we were not able to exactly calculate the percentage of total plant energy which is attributable to water pumps. Instead, we used an assumption range based on comparable case studies and ran the payback analysis assuming 55-70% in 5% increments (Ghaffour et al., 2013). The results of the payback analysis are shown below in Table 25.

Table 25: Illustrative Payback Period For Energy Recovery Devices (Years)
Created by Authors

Energy for water pumping / total plant energy usage (%)	Reduction in energy requirements for water pumping due to ERD installation (%)				
	10%	15%	20%	25%	30%
55%	22.4	16.0	12.4	10.2	8.6
60%	20.9	14.8	11.5	9.4	8.0
65%	19.5	13.8	10.7	8.7	7.4
70%	18.4	13.0	10.0	8.2	6.9

Across all scenarios, the payback period ranges from 6.9 to 22.4 years and falls within the 30 year expected useful life of the devices. This means that the expected cost savings from the energy recovery devices is expected to exceed the upfront investment of installing the devices. In the midpoint scenarios — which assume a 20% reduction from energy recovery devices and that water pumps consume 60-65% of total plant energy — the expected payback period is roughly 11 to 12 years

Next, we calculated the lifetime cost savings ($000) resulting from the energy recovery devices across the same range of scenarios. Lifetime cost savings ($000) is calculated as cumulative energy cost savings over the 30 year device lifetime ($000) less the upfront cost of installing the devices ($000). The results of the lifetime cost analysis are shown below in Table 26.

Table 26: Illustrative Lifetime Cost Savings ($000's) For Energy Recovery Devices
Created by Authors

Energy for water pumping / total plant energy usage (%)	Reduction in energy requirements for water pumping due to ERD installation (%)				
	10%	15%	20%	25%	30%
55%	$94	$238	$383	$527	$672
60%	$120	$278	$435	$593	$751
65%	$147	$317	$488	$659	$830
70%	$173	$357	$541	$724	$908

Across all scenarios, the energy recovery devices generate positive lifetime cost savings for the desalination plant (which aligns with the results of our payback period analysis). The total incremental savings vary greatly based on the performance of the devices and overall energy intensity of the water pumping at this specific plant. In the midpoint scenarios — which assume a 20% reduction from energy recovery devices and that water pumps consume 60-65% of total plant energy — the expected lifetime cost savings range from around $435,000 to $490,000. As such, our analysis suggests that these devices are a worthwhile investment and have the potential to improve overall plant economics.

Conclusion: Energy Recovery Device Installation

Our conclusion is that energy recovery devices are a logistically feasible and economically viable installation which can generate material cost savings for the Cape May desalination plant. Across a wide range of scenarios, the devices are expected to consistently generate incremental cost savings and achieve a payback period well within the useful life of 30 years. In the midpoint scenarios — which assume a 20% reduction from energy recovery devices and that water pumps consume 60-65% of total plant energy — the expected payback period is roughly 11 to 12 years and expected lifetime cost savings range from around $435,000 to $490,000. Based on this analysis, we expect that installing energy recovery devices would not only improve plant longevity but would also reduce operational costs and generate an attractive return on the utility's upfront investment.

7.4. Solar Expansion

In an effort to identify ways to reduce costs for Cape May, we designed a theoretical on-site solar installation. The goal of the on-site solar installation is to reduce the costs associated with the utility bill. We assumed that the roofs for the design are strong enough to carry the load of the solar array. This assumption should be confirmed with engineers.

7.4.1. Proposed Solar Expansion

The utility bill analysis revealed that a large amount of the cost can be offset by onsite solar generation. Using HelioScope, a solar design program, we designed a theoretical installation of a photovoltaic solar array on the existing rooftops of the desalination facility as well as the rooftop of the future desalination building. The goal was to maximize the solar generation to offset as much energy consumption of the utility as possible. However, given the limited amount of space the maximum nameplate capacity of the system is roughly 133.8kW with a capacity factor of 14.3%. The capacity factor is the ratio of the actual annual energy production over the theoretical maximum production if producing 24 hours a day (PV-AC-DC | Electricity | 2021, n.d.).

Our analysis focuses on an ownership model whereby the utility retains full ownership and control over the solar array. This approach was pursued after conversations with the stakeholders who indicated their desire to not sell or share ownership. The current site does benefit from a minimal amount of solar, for purposes of our analysis we assumed a brand-new system that covers the existing solar and expands the total system capacity.

The following sections describe the proposed design of the solar installation, an analysis of the utility bill that identifies the saving potential, and additional value drivers including renewable energy credits and state and federal incentives. There is also a description of the various operating expenses. The result of installing the 133.8 kW solar systems are average savings of roughly $40,000 per year for 30-years.

Figure 17: Solar Array Design
Created by Authors, Source: HelioScope

7.4.2. Solar System Design/ HelioScope

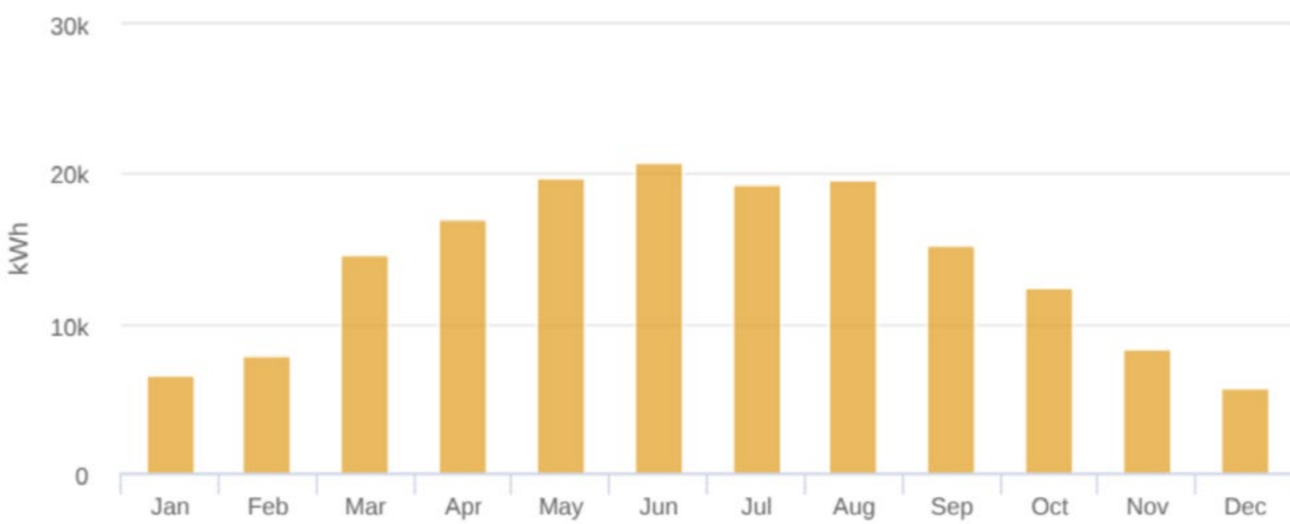
In order to bring the potential future solar installation recommendation to life, we sought to understand the local landscape, building options for installation and weather patterns. We wanted to provide a design for a potential future solar installation. In order to help us generate a solar installation, we leveraged HelioScope, a commercial solar software used to design commercial and industrial solar projects.

The tool allowed us to design a solar system that accounts for real weather data in the local area. Consequently, our design accounts for seasonality and weather patterns. Furthermore, it allows us to account for soiling impacts, which is the reduced efficiency caused from dirt and or snow coverage of the panels. Thus, soiling is heightened in the winter months when snow is more likely. Additionally, there is a large water tank at the site. The shading effect caused from the water tower is also captured in the production figures. Trina solar modules and Sunny Tripower inverters were used. Strings of photovoltaic (PV) cells are connected to form a solar module or more commonly called a solar panel (Solar Photovoltaic Technology Basics, 2019). Inverters convert direct current (DC) electricity to alternating current (AC). This is a critical conversion as solar modules generate electricity in DC, but the grid uses AC (Oltmann, n.d.). For financial modeling purposes, we assumed an annual degradation factor of 0.5% annually. Degradation captures the reduced output of the system as it ages. We also assumed an asset useful life of 30-years for modeling purposes (End-Of-Life Management for Solar Photovoltaics, n.d.). The full HelioScope report can be available upon request.

Table 27: Illustrates Key Characteristics Of The Proposed Solar Design
Created by Authors, Information source: HelioScope

System Characteristic	Value
Nameplate Capacity (DC)	133.8 kW
Annual Production	167.5 MWh
kWh/kW	1,252.4
Capacity Factor	14.3%

Figure 18: Illustrates KWh Produced In Each Month Representing The Seasonality Of The Location
Created by Authors, Source: HelioScope



7.4.3. Utility Bill Analysis

In order to understand the total amount of energy that can be offset by on-site solar and the resulting associated cost savings, a utility bill analysis was conducted. A detailed description and breakdown of the utility bill can be found in Section 7.3.1.

Atlantic City Electric, an Exelon Company, electricity bills for each month in 2024 were analyzed. Electrical consumption reached a low of 67,993 kWh in April and increased to a peak of 168,710 kWh in August. The August peak is expected given the summer demand surge from tourism as further described in Section 2.3.2. The total consumption rate of $0.17/kWh was calculated by taking the total cost of electricity in 2024, $218,863 and dividing by the total consumption in 2024, 1,296,315 kWh in 2024.

As the next step, the energy rate was broken into two components: a fixed rate and a variable rate. The variable rate was determined by analyzing all of the avoidable costs in electricity bills, which accounts for any charge that is determined on a kWh basis as opposed to on a capacity basis (kW) and dividing it by the total consumption. The variable rate in 2024 was $0.12/kWh.

Table 28: Illustrates Key Utility Analysis Outputs
Created by Authors

Total Energy Use	1,296,315 kWh
Total Energy Rate	$0.17 /kWh
Variable Rate	$0.12 /kWh

7.4.4. Value Streams: Energy Offset & Incentives

This section analyzes the various value streams of the proposed Cape May solar array. The project's value comes in the form of savings via offsetting the purchase of electricity from the utility, state renewable energy credits, federal tax credits, net metering, and depreciation. These value streams are described further and can be thought of as revenue drivers for the project.

Energy Offset

As described in the Utility Bill Analysis section, Cape May can avoid the variable rate of electricity in each period. Therefore, for every kWh of solar generation, Cape May saves (offsets) approximately $0.12. An annual inflation factor of 2.00% is applied to the $0.12. In the first year of operation, the solar array produces 167,520 kWh of energy. Consequently, the energy produced saves about $20,102 in the first year.

New Jersey State Solar Credit (SCREC II)

Commonly, renewable energy assets earn renewable energy credits (RECs). These RECs act as an additional revenue source for the asset. When a renewable energy project generates 1 MW of energy, it creates 1 REC. (States have various REC programs). The New Jersey Board of Public Utilities developed an Administratively Determined Incentive (ADI) Program. Under the ADI, an SREC-II (Solar Renewable Energy Credit) is available. For a project under 1 MW and owned by a public entity, the value of the SREC is $130 (Administratively Determined Incentive (ADI) Program, n.d.). Therefore, for every kWh of energy produced the solar array receives $0.13. This creates an ancillary revenue stream for the project, which further reduces the electrical bill. In the first year of operations, this generates $21,778.

Federal Incentives Investment Tax Credit (ITC) And Production Tax Credit (PTC)

Many renewable energy technologies such as solar are eligible for either a federal investment tax credit (ITC) or a production tax credit (PTC). The ITC is based on a percentage of the cost of the system and is paid in full at the start of operations. The PTC is based on the annual production of the system and is paid out over a 10-year period (Batra & Reddy, 2022). Owners can opt for either the ITC or the PTC. Generally speaking, an owner would pursue an ITC in areas that have a low-capacity factor and high construction costs. On the other hand, an owner is more likely to pursue a PTC in an area with a high-capacity factor and low construction costs (Batra & Reddy, 2022). For the proposed Cape May solar system, an ITC was assumed.

Various financing structures are used to optimize the value of the tax credits. Prior to the Inflation Reduction Act (IRA), signed in 2022 under the Biden Administration, the ITC and PTC could only be used to offset the tax liability of the system owner. Therefore, many developers and public entities could not capture the value of the ITC or PTC because they have low or no tax liability. To still realize the value of the tax credit, complex tax equity partnerships are created (Martin, 2021). Tax equity partnerships bring in a third-party investor who contributes capital to the project and extracts the tax credit (and many times the depreciation) benefits. Prior to the IRA, to optimize the economics of the project Cape May would have needed to seek a tax equity investor.

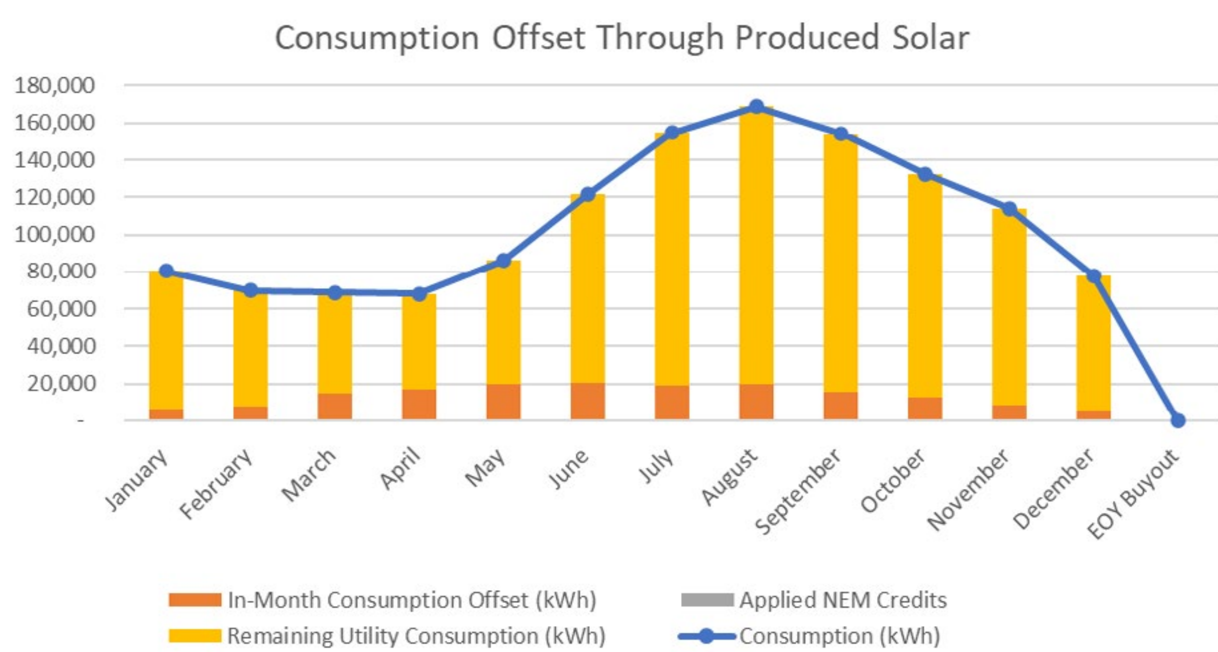
The IRA introduced two critical features. The first is the concept of transferability, which allows an owner to sell the tax credit to a third-party buyer that is not an equity investor in the project. These credits are sold at a discount usually between 90 to 92 cents on the dollar (Martin, 2023). (Transferability is not discussed further as it was not used for analysis. However, if this option is pursued Cape May would need to identify a third-party buyer of the credit such as a large corporation). The second critical feature is direct pay. Direct pay allows not-for-profit entities to receive the tax credit in the form of cash directly from the Internal Revenue System (IRS) (Summary of Inflation Reduction Act Provisions Related to Renewable Energy | US EPA, n.d.). Simply put, if Cape May were to create an ITC of $100, then the IRS would send them a $100 check. Direct pay was used for the Cape May analysis. The ITC for a system size that is less than 1 MW is 30% (Tax-Exempt Entities and the Investment Tax Credit (§ 48 and § 48E), n.d.). Projects may be eligible for tax credit adders or bonus credits, which can increase the ITC amount up to 70%. Examples of The ITC bonus credits include Energy Community, Domestic Content, and Low-Income Community. Projects must prove that they qualify for the bonus credits (Tax-Exempt Entities and the Investment Tax Credit (§ 48 and § 48E). However, to maintain a conservative analysis these adders were not considered and bonus eligibility falls outside the scope of this analysis. The cost of the Cape May system is estimated at $2.00/w or a total cost of $267,600 (this includes a developer fee of $0.40/w). This results in an ITC amount of $80,280 which is paid in the first-year of operations. It is important to note that the analysis is based on the federal policies that are in place at the time of this report. The federal and state policies should always be reviewed in their most current form before proceeding with any project.

Net Metering Feasibility

New Jersey has a net metering program for solar installation. In periods where a system generates more electricity than is required, the owner of the solar array is able to sell the excess electricity to the grid and is compensated at the full retail value of the electricity. This compensation is then rolled forward to offset the bill in periods where the solar generates less than what is consumed. At the end of the year, the system owner receives a payment for any excess generation (Net Metering and Interconnection, n.d.).

Unsurprisingly, Cape May would receive little to no benefit from the net metering program. The total system capacity that is available at the site only generates a fraction of the total consumption in any given month. Therefore, the solar generation would likely never be in excess of consumption in any month. This is illustrated in the figure below.

Figure 19: Illustrates Energy Consumption Offset By Solar Generation
Created by Authors



Accelerated Depreciation

Depreciation is a tax deduction that enables the recovery of the cost of certain property types (Publication 946 (2024), How To Depreciate Property | Internal Revenue Service, n.d.). Typically, assets utilize the straight-line method of depreciation, which recovers the cost over the useful life of an asset. For example, if a solar asset costs $300 and the useful life is 30-years, then each year $10 is depreciated. Thus reducing taxable income by $10 each year for 30-years.

Solar assets benefit from the ability to utilize Modified Accelerated Cost Recovery System (MACRS), which is an accounting mechanism that depreciates the asset across a 5-year period as opposed to less accelerated accounting methods such as straight-line. The accelerated depreciation creates large non-cash expenses across the first 5-years of the project, which are used to reduce taxable income (Depreciation of Solar Energy Property in MACRS, n.d.). A reduction in taxable income is a source of value.

Cape May cannot benefit from accelerated depreciation because it is a public entity that does not have taxable income. However, under certain financing structures that are outside the scope of this analysis, Cape May could pass the value of accelerated depreciation to a third party. This would help optimize the overall value of the solar array.

7.4.5. Solar Expenses

The cost of installing the proposed solar project is estimated at $1.60/w ($214,080) with an additional $0.40/w ($53,520) developer fee (Cost Basis for the ITC and 1603 Applications, n.d.). This results in a total system cost of $267,600. Regarding operating expenses, the solar model accounts for operations and maintenance (O&M), insurance, and Other. O&M costs are estimated at $22/kW per annum and escalate at 2% to track inflation (Solar Photovoltaic System Cost Benchmarks, n.d.). Insurance costs are estimated at $10/kW per annum (Smith, n.d.). Other costs are approximated at $8/kW. Other costs are a line item to help conservatively account for operating costs. The average total operating costs across 30-years is $6,389.

7.4.6. Key Results Of Solar Expansion & Conclusion

The annual savings are the summation of the energy savings created from the energy generation, the revenue received from the SCREC-II program and the federal ITC payment less operating expenses. On average annual savings of approximately $38,996 are realized, excluding any ITC transfer payment. Over a 30-year asset life this generates total savings of $1.17M. These savings increase when the $80,280 ITC transfer payment is incorporated. When the ITC payment is included, the payback period of the system is approximately 6-years. Without the ITC payment the payback increases to 8-years. A model print out can be available upon request. Under the current federal and state incentive policies, pursuing on-site solar can reduce utility bill expenses year over year across the project's 30-year asset life.

Table 29: Illustrates Year-1 Financial Model Outputs
Created by Authors

Key Results of Proposed Solar Design Year-1	
Production	
Production (kWh)	167,520
Savings/Revenues	
Energy Savings from Utility Bill Offset	$20,102
SREC-II Revenue	$21,778
Direct Pay ITC (30%)	$80,280
Operating Expenses	
Operations & Maintenance	$(2,944)
Insurance	$(1,338)
Other / Misc.	$(1,070)
Earnings Before Interest Tax & Depreciation (EBITDA) (considered as savings)	
EBITDA	$116,808
EBITDA without ITC	$36,528

7.4.7. Other Consideration For Solar Expansion

It is important to note that both federal and state level incentives can be cancelled or changed. Therefore, it is critical to review the latest rules and eligibility for incentives before developing any solar project. Additionally, ownership models of solar assets can be complex. Consequently, seeking legal advice is crucial for the long-term success of a project. Finally, many solar projects seek non-recourse financing (project finance) to help reduce the upfront cost of the system. It may be advisable to seek out friendly financing partners such as development or green banks.

Conclusion

8.1. Circularity

Over the course of this research project, the Water Circularity Team identified several potential solutions which did not ultimately end up being pursued. This section will address those solutions that may someday prove relevant to the sustainability of Cape May City's water supply.

One such solution was the use of Managed Aquifer Recharge (MAR) strategies to manually replenish water within an aquifer. This umbrella term covers a variety of strategies that have grown increasingly common to improve and supplement subsurface freshwater resources. Among the many co-benefits are reducing land subsidence and saltwater intrusion as a result of aquifer over-withdrawal. While the "MAR strategy" umbrella covers numerous approaches, one in particular stood out as particularly relevant to Cape May City.

Aquifer Storage and Recovery (ASR) technology has been employed to great effect in Cape May City's neighboring municipality of Wildwood, New Jersey. Wildwood is located on the same formation of barrier islands and faces many of the same challenges as Cape May City, including a similar influx of seasonal residents. The primary difference in their water supply infrastructure stems from Wildwood's ASR facility. This facility is the oldest such facility in the United States and has supplied the municipality with fresh water from the Atlantic City 800 foot sand aquifer since 1968. What distinguishes this facility from Cape May City's desalination plant is that the ASR facility injects treated fresh water back into the aquifer during the offseason. This process creates a large bubble of treated water around the injection site within the aquifer for later withdrawal during times of peak water demand. ASR technology has thus enabled Wildwood to effectively accommodate the variability in its seasonal water demand. As the issue of increasing saltwater intrusion continues to complicate Cape May City's desalination processes, the city may consider employing ASR technology to mitigate further intrusion while alleviating some of the seasonal stress on its water supply infrastructure.

In addition, the implementation of Green Infrastructure such as bio-swales, rain gardens, and stormwater tree trenches in line with Cape May City's Comprehensive Plan can help capitalize on the region's significant annual rainfall long-term toward the replenishment of its aquifers.

8.2. Desalination

While desalination has proven essential in Cape May's water security strategy to ensure potable water access amid saltwater intrusion, the process is not without its long-term trade-offs. Desalination is inherently an energy-intensive process and produces a saline concentrate byproduct. This raises concerns around sustainability, cost, and environmental impact. Cape May's current system draws brackish water from the Atlantic City 800-foot sand aquifer- a resource that is being depleted faster than it can naturally recharge. Continued withdrawal not only risks exacerbating saltwater intrusion but also challenges the viability of this approach as a permanent solution.

In the long term, it is crucial for Cape May to look into diversifying its water portfolio beyond aquifer-based desalination. One potential avenue is exploring a dual-source desalination strategy that includes direct use of the Atlantic Ocean. Given the city's geographic positioning, this approach could relieve pressure on brackish aquifers while leveraging abundant saline sources. A future facility could alternate between ocean and brackish sources based on seasonal demand, regulatory flexibility, and operational cost. This innovative approach may help the city balance resilience with efficiency.

Additionally, Cape May can capitalize on its unique geography by investing in rainwater harvesting infrastructure. Lakes such as Lake Lily offer an opportunity to be converted or enhanced as rainwater reservoirs, providing a supplemental water source for treatment or indirect recharge. Rainwater can also be stored and channeled during wetter months to reduce peak reliance on desalination during the summer. Integrating green infrastructure with smart storage systems would align with the city's broader climate adaptation and circular water goals.

While desalination remains an important part of the City's water future, its sustainability may well depend on thoughtful resource diversification, improved energy efficiency, and proactive exploration of alternative freshwater sources.

8.3. Demand

Reducing water demand could be a key component to mitigating Cape May City's current water issues. According to our water usage analysis (Section 6.1), large-scale hotels account for the vast majority of the top 100 water consumers in Cape May City. We recommend Cape May City to initially focus water conservation efforts on these large-scale hotels. Implementation of water conservation initiatives (e.g. tiered pricing or rebate programs) can be a complicated endeavor when trying to account for all types of water consumers (residential and commercial). By narrowing the scope to large-scale hotels, implementation processes are simplified and the largest water consumers are the focus. Note that while we recommend prioritizing large-scale hotels, we encourage Cape May City to extend water conservation efforts to all residential/commercial water users in the future.

We created a water conservation proposal that leverages a three-pronged approach: outreach and engagement, incentivizing through rebates and disincentivizing through tiered pricing. Within this water conservation proposal is a suggested implementation timeline. This timeline strategically orders the roll-out of each initiative in a fashion that could optimize the overall water demand reduction of our proposal. Our suggested implementation timeline could also improve the reception of tiered pricing by placing outreach and engagement initiatives before the tiered pricing roll-out.

Long-term water stewardship could increase the lifespan of the future desalination plant and strengthen the overall resiliency of Cape May City. We recommend Cape May City to continue expanding and improving upon the water conservation initiatives in this report for years to come. As climate change intensifies, Cape May City could greatly benefit from strong water stewardship in preparation for increasing temperatures and unpredictable rainfall patterns. By maintaining long-term commitments to water conservation, Cape May City can build a resilient future for itself.

8.4. Finance

In order to guarantee access to reliable potable water for years to come, Cape May City needs to ensure that municipal water infrastructure is operated sustainably. Economic viability is a key element of sustainable operation and minimizes the financial burden on the municipality and taxpayers. The Cape May Water & Sewer Utility has demonstrated admirable fiscal discipline in the past and should seek to continue that tradition. As Cape May City evaluates long-term water supply alternatives, it should ensure that any chosen initiative is economically viable.

In the near-term, we believe that launching a water-efficiency rebate program would achieve a meaningful reduction in water demand from large commercial users. A reduction in water consumption would prolong the useful life of the existing desalination plant and extend the lifetime of the aquifers. Our analysis suggests that this impact could be achieved on a relatively cost-effective basis and would have the added benefit of supporting the local tourism industry.

In the long-term, we recommend that Cape May City install energy recovery devices and develop onsite solar generation for the proposed greenfield desalination plant. Energy recovery devices have been shown to be successful in reducing energy consumption at desalination plants. These devices improve energy efficiency by allowing the plant to achieve the same output with less energy input and can generate meaningful cost savings over the lifetime of the asset. Onsite solar generation would reduce the amount of electricity that the desalination plant needs to purchase from a third-party provider. This would result in significant operating costs, in addition to the financial benefits which can be claimed from the state and federal governments for developing clean energy resources. By pursuing energy efficiency and clean energy generation, Cape May City could improve both the financial viability and environmental sustainability of the next desalination plant.

We hope that our illustrative financial analyses will help Cape May City decision-makers confidently weigh social, environmental, and operational trade-offs with net financial impact. Moving forward, we recommend a few next steps for Cape May City:

1. Refine the underlying assumptions of our analyses to ensure with greater certainty that proposed actions have the intended financial impact.

2. Develop a framework to evaluate trade-offs: social, environmental, operational, and financial.

3. Increase tracking and reporting of financial and energy data. For example, monitor actual energy consumption of the desalination plant to ensure that operational adjustments drive actual results. Similarly, more detailed cost tracking at the level of the desalination plant would allow the utility to make better, data-driven decisions to improve profitability.

Ultimately, having a clear view of the financial impact of new initiatives can allow the city to continue to maintain strong fiscal discipline and operate infrastructure in a sustainable manner.

Closing Statements

Cape May stands at a unique crossroads where its natural beauty, economic vitality, and water infrastructure resilience must be carefully balanced to ensure a sustainable future. Through this project, our team has had the opportunity to support the City's efforts by analyzing the current water system, exploring pathways for circular water use, recommending operational and technological improvements to the desalination plant, and designing demand-side solutions that are financially viable and community-oriented.

Our findings reflect not only the technical and financial feasibility of proposed strategies, but also the critical importance of engaging Cape May's residents, businesses, and seasonal visitors in shaping a water-secure future for the city. From enhancing efficiency at the plant to empowering residents with redesigned utility bills, the strategies presented in this report are rooted in the understanding that meaningful, lasting change comes from within the community.

We are deeply grateful to the City of Cape May for welcoming us with open arms and sharing invaluable insights into the City's operations, culture, and commitment to sustainability. The hospitality extended to our team during the site visit — from city officials to plant operators to community members, greatly enriched our understanding of local challenges and opportunities. It was an honor to contribute to this important work, and we thank you for the opportunity to learn from and alongside such a dedicated and inspiring community.

Appendix

10.1. Transcript Of Interview: Walter Meyer, Landscape Architect, Founding Principal At Local, Irrigation With Concentrate

Q: There are some opportunities to irrigate city landscaping, and possibly small agricultural operations with concentrate in Cape May City. How can you maintain soil health while irrigating with a low salinity irrigant? What are the best practices?

A: There are species that can handle low-level salt. [Cape May City is] in the right zone. Most species can't live in one to three percent salt in the water or soil but [the concentrate] is below the margin for salt-tolerant species.

- On the civic planting approach, the issue is in terms of rotation of plants. It's very different from agriculture where you might have crop rotation and the plant species may vary over time. In urban environments it is static for a while. Once salt accumulates to more than one to three percent then it starts to become a problem. It makes plants less efficient at uptaking nutrients that exist in the soil and then people have to fertilize to make more nutrients available than are normally needed and plants are less efficient at that uptake. Eventually, you'll get dead zones where you can't plant anything except seaside species, things that grow in the dunes for example. The big deal is salt accumulation. It eventually is a problem. There are ways to ameliorate salt - it mostly requires a lot of freshwater flushing. Also, in cities, usually when you plant that species will be there for years into the future.
- With agriculture, they tend to shift crops seasonally, they call it crop rotation. Sometimes they'll even change a crop. They'll grow a crop for five years and switch to another crop for five years. So there's different cycles of crop rotation. Also, the market may want to shift. One crop becomes less productive or has less capacity. So the issue there is when it comes to food, you are limited on things you can grow that can grow in salt. It's moreof a challenge with agriculture. Once you salt to half a percent or one percent in the soil, it slowly narrows down what you can plant and not plant there. It can apply to agriculture but it's going to limit what you can plant. It can apply more aptly to urban environments (e.g. gardens, landscaping, etc.).

Q: Diving deeper into salt accumulation, would irrigating with the concentrate result in soil salinity levels reaching one to three percent salinity?

A: You would need to monitor soil salinity. It depends on the soil type. For example, sandy soils, which is Cape May, [salt accumulation is] less of an issue. What happens is salt tends to bind to organic compounds. Soil that is sand based doesn't hold on to [salt] compounds as much. [Salt] sives through the sand down to the groundwater versus clay soil, which you get more up in the mountains or in wetland areas. Clay has organics and compounds will bind to the organic matter in the soil and stick around for a while. Coastal environments are already salty and [the salt is] not going to accumulate as much in sand as it does in clay.

Q: What volume of freshwater would you have to use in order to do freshwater flushing?

A: Sand cleans faster than clay for the same reason that the compounds bind to clay. [Hypothetically], you may need four times as much water in clay as you do in sand to polish out that salt. There are also other things you can do to ameliorate the soil. There are also compounds you can use [to ameliorate soil]. Gypsum powder is one thing you would apply after a garden is submersed in sea water after a flood.

Q: What kind of water infrastructure do you recommend for delivering saltier water to consumers?

A: There could be an issue. Not a lot of places have copper pipes but with copper, when you use acidic pH, it tends to leach copper into the water. Thankfully, salt water is more alkaline so with copper that will be less of an issue. With plastic pipe, like PVC, it's probably less of an issue. However, there's a lot of iron [and steel] pipe that's used that could be an issue because when you introduce salt you can accelerate rust. You should shift to a plastic pipe for moving salty irrigation water around. The adhesive used on pipe joints could be impacted by the salt overtime. What you would do is switch to pressure welds that don't use adhesive.

Q: What are some salt tolerant plants you would recommend for Coastal New Jersey?

A: With climate change, there are more species available in New Jersey now than were available before. There's types of Bermuda grass and Seashore paspalum that used to not grow in New Jersey so well. However, two things are happening. With climate change the climate zones are moving north. Also, the selections of the grass are starting to be selected for more cold hardiness. So between the cultivation of the grass and the new varieties that can handle cold weather and with the climate zones migrating north you start to get an intersectionality of grass from the South East that are more salt tolerant. They used to be used in Georgia and now they can be used in the Carolinas. We're pretty close to where they will come up to in New Jersey. Another thing to consider besides grasses is to look at the habitats. Look at the dune habitats of Cape May and the north Delaware coast. In that zone you'll get species that are starting to apply to New Jersey. Beyond just grasses there are a lot of other options, like dune grasses, small shrubs, and pitch pines. There's a tree called a Virginia Pine that would make sense here and can handle the salt. So if you were to do a street tree or a park planting you would use things from the Cape May dune habitats and the north Delaware coastal habitat.

Q: Are there examples of successful commercial partnerships between consumers and generators of alternatives to irrigant?

A: Yes, in Florida there's a lot of golf courses that have been [irrigating with] gray water since the '70s. They may not call it concentrate, they just call it gray water. Gray water historically is a little salty in Florida. You have a mix of all kinds of things from the house that are being filtered just enough for you to use for irrigation. The economic benefit was in cost avoidance. Every gallon that they reuse is a gallon that they don't have to buy.

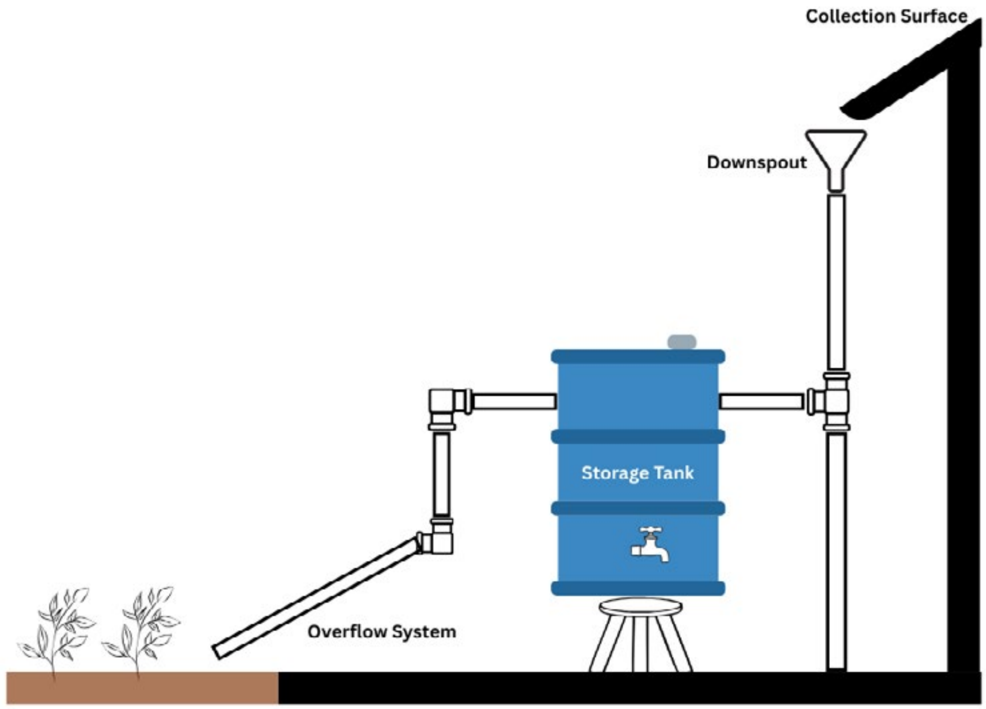
10.2. Rainwater Harvesting

While it is not part of our immediate recommendations, the Demand Team discussed rainwater harvesting with Cape May City. This section will provide a brief overview of rainwater harvesting systems along with cost considerations.

Rainwater harvesting is a widely adopted strategy that yields a variety of water management benefits. Through capturing rainwater, these systems help supply water towards non-potable uses. Generally, this non-potable water is used for irrigation; however, rainwater systems with higher complexity can divert this water to other applications such as flushing toilets. This then could offset the water demand that would have otherwise been supplied by the desalination plant. Especially during summer when water demand is peaking and irrigation needs are higher, rainwater harvesting could play a role in relieving pressure off the desalination plant. Beyond offsetting water demand, rainwater harvesting also mitigates erosion and stormwater issues.

As alluded to above, rainwater harvesting systems have a range of complexity. At the most basic level, a rainwater harvesting system has a collection surface (generally a roof), gutters and a downspout, a storage tank and an overflow system. The figure below illustrates how all these components go together.

Figure 20: Low Complexity Rainwater Harvesting System
Created by Authors



The majority of components for these low complexity rainwater harvesting systems can be purchased in kits. The most economical option for these kits generally start around $150 per kit and increase in price depending on the features or complexity. These kits serve as a low-cost option that Cape May City can consider for an entry point into rainwater harvesting. Community gardens or schools are a great place to introduce these systems. This provides an educational opportunity to teach the community about not only rainwater harvesting but also the importance of water conservation in Cape May City. From there, the city can gauge the success of these smaller systems and consider building out rainwater harvesting to larger applications.

10.3. Case Study: North Port, Florida, BWRO Facility With Low Pressure PX, Pressure Exchanger

In Sarasota County, Florida, the City of North Port constructed a new BWRO facility with a capacity of 2.0 MGD, to address rising salinity in its groundwater. The concentrations of the water extracted reached as high as 13,000 mg/L tds (Littrell et al., 2022). This BWRO plant was designed from the ground up for efficiency, as the plant integrated Low-Pressure PX devices on both of its RO skids. These energy recovery devices have the potential to operate at up to 97% efficiency under optimal conditions, resulting in substantial reductions in energy consumption, and operational costs (Littrel et al., 2022).

At the new facility's initial operating conditions, the BWRO plant achieved an energy savings of 0.44 kWh per cubic meter, and is projected to achieve up to 1.1 kWh/m^3 as salinity levels continue to rise. The PX devices also allowed for a 20% reduction in pump flow, which translates to a 33-horsepower decrease in motor requirements, and an estimated $95,000 in capital cost savings due to pump and motor downsizing (Littrell et al., 2022).

Each reverse osmosis skid delivers between $11,680 to $105,850 in annual energy savings, with the variation directly tied to the TDS of the feedwater. At lower TDS levels around 3,500 mg/L, savings seen at this plant are closer to $11,680 per skid. At higher TDS concentrations up to 13,000 mg/L, the ERD operates even more efficiently, resulting in savings of up to $105,850 per skid. Altogether, this results in the total annual savings for the full facility to range between $23,360 and $211,700 (Littrell et al., 2022).

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